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APRIL 1958

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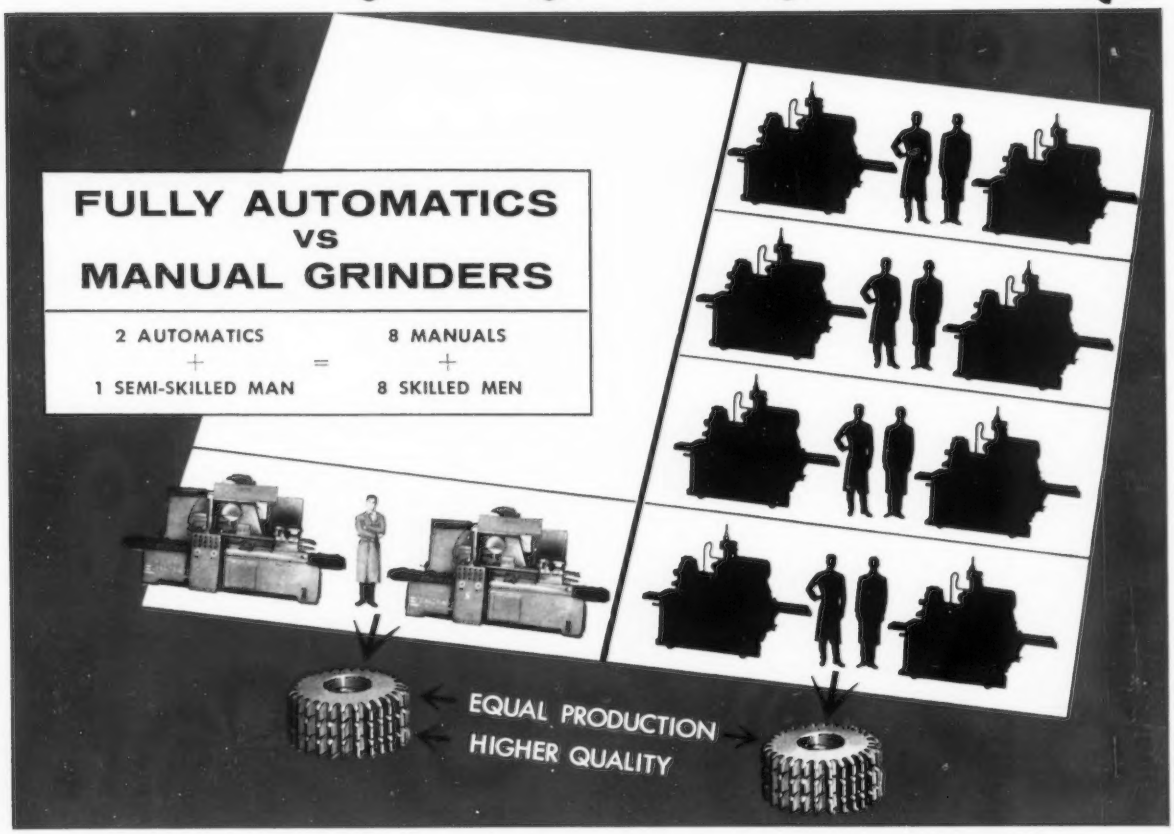

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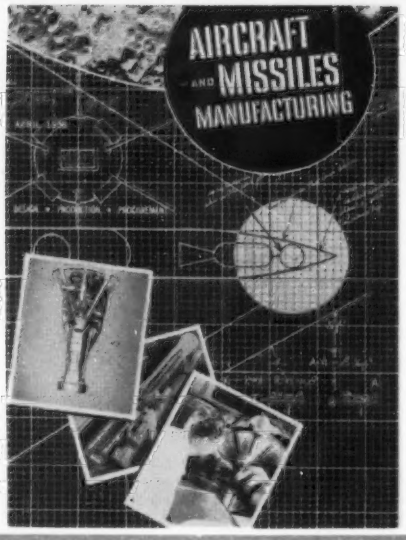

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All implements of material progress, regardless of extent of complexity, or magnitude, originate first in the intangible form of concepts through a vaguely known process of the human brain. The discreet delineation of such concepts into intelligible design permits effective translation into tangible results. The Vanguard project is an outstanding example of the above process directed to the conquest of the gravitational barrier which has kept man earth-bound, both ideologically and physically.

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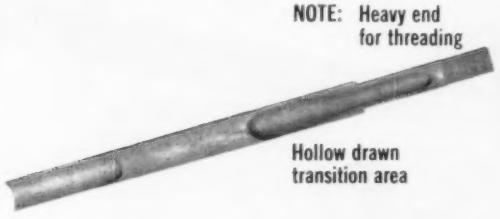

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How would you like your Space Agency?

You can have it various ways. Take your pick: controlled by the military, or controlled by civilians; made up of professional soldiers, or composed of scientists, scholars, and businessmen. Do you want the agency to be of national or international scope?

These are some of the questions you may ponder upon, but not too long. A decision must be reached before any single nation attempts to stake a claim in outer space. The time for that decision is now. Unless we start the foundations of a space agency of broad altruistic scope, the Moon, Mars, and the vast beyond will continue to be considered as potential military objectives.

Most of us certainly believe that a Space Agency should exist, preferably at an international level, and believe also that it should be composed of intellects capable of fathoming the significance of this unique moment in the lurid history of earthlings. Without a rebirth of thinking, at this stage, man will merely succeed in extending the fallacious values and consequent problems, he has created on earth, to newer outposts.

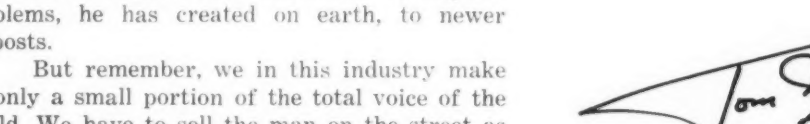
But remember, we in this industry make up only a small portion of the total voice of the world. We have to sell the man on the street as well as the legislators.

To most lay people, the subject has been utterly fantastic until a few short months ago. And now, we generally discuss "what price the Moon" and manned re-entry vehicles.

Let us publicly express our space-agency beliefs based on sound, logical reasoning. We should not go abstract, but disseminate data intelligible to the average man who is not closely associated with the aircraft and missile industry.

One of the things we must do is publicize the broad implications of our engineering advances, so that these advances will not be used only for political or military gain. After all, it is industry that strikes forth with the new developments. If these developments, however, are held back by the military and government, and then released at an opportune time, they can be used as a political football.

Shall we extend our earthly problems beyond this planet? Let us not make the Universe an arena for power politics and military might.



Editor

power from ram air

light weight accessories extract emergency and auxiliary power from air stream

by John Kevern

The airstream over a high performance jet aircraft provides an ideal source of power for emergency electrical and hydraulic power when the primary engine driven systems fail.

Ram air accessories have been developed that translate the kinetic energy of the air passing through a windmill to usable power in a matter of seconds.

Tapping this energy presents several critical problems:

- "Popping" an accessory windmill into a windstream that may be over Mach 1.
- Providing reliable operation over temperature and pressure variations encountered from sea level to 60,000 ft.
- Maintaining a constant power output regardless of windstream velocity (100 to 750 kts).
- Shielding bearings against contamination of rain, dust and dirt.

These ram air accessories are refined cousins of the wind driven pumps common on

Power for pumping fuel, and winding drogue hose is obtained from a ram air powered turbine, in the Navy "buddy refueling" unit. Being ground checked here, unit is 17 ft long.

power from ram air

continued

agricultural dusting planes. Emergency units find wide application on small military fighter aircraft.

An interesting example of a ram air unit furnishing auxiliary power is in the Douglas in-flight fueling store, used in the Navy "buddy fueling" system. This self-contained refueling pod is powered by a four-bladed ram air turbine that provides complete power for running out the drogue, pumping the fuel, and reeling in the hose.

Windmill Materials Design

The windmills which extract wind stream energy for the ram air accessories are opposite in purpose, design, and appearance to aircraft propellers. Since windmills extract, rather than deliver power, thrust and torque relationships are negative.

Drive blades, hubs and spinners are of anodized 75 ST aluminum, forged and ground to size. The hubs are split type for ease of machining. All inner parts are of cadmium plated steel, except the coordinator, which is chromium vanadium steel, and the governor parts which are stainless steel.

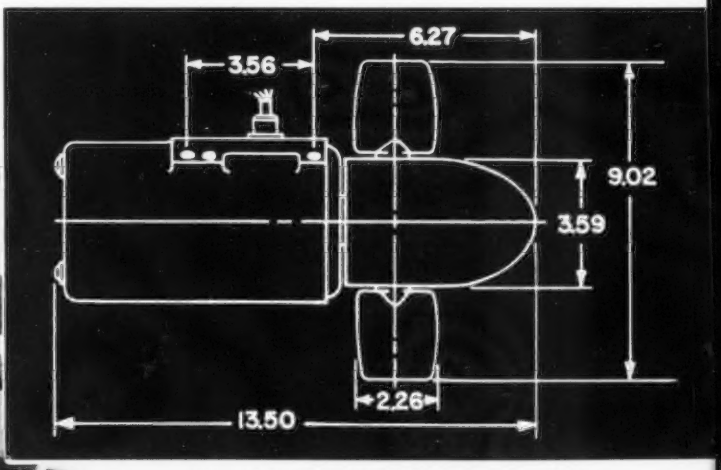
The windmill converts the energy of air passing through its blades, in unit time, to usable power. Since power (P) is equal to force times velocity, blade size is an important consideration in designing a windmill. The power in a cross section of the airstream described by the blade tips is:

$$P = \tfrac{1}{2} \rho \pi R^2 V^3$$

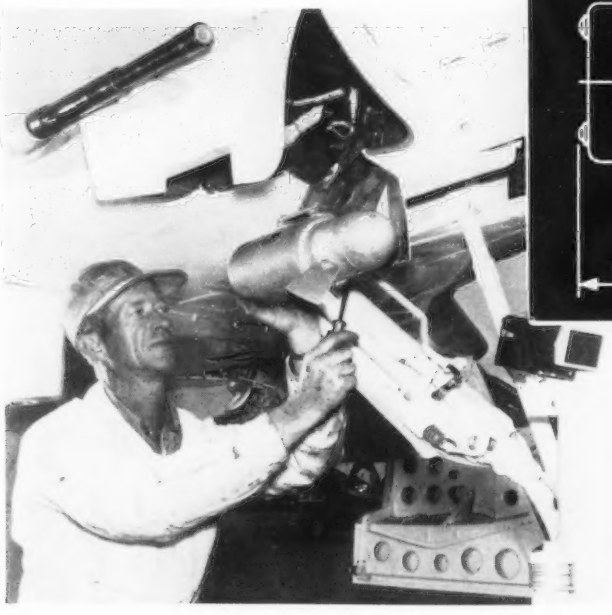
where "ρ" is the density of the air, "R" the blade radium, and "V" the air velocity. An ideal windmill can absorb about 60 percent of this power. In order for a windmill to approach this ideal, the ratio of rotational speed of blade tips to forward velocity of the blade must be high. On units in operation it is about 1 to 4.

The number of blades for a maximum power output decreases as the tip speed ratio increases. A windmill with two blades has maximum efficiency at high speeds, while a multi-bladed unit performs best at low tip speeds.

For this reason two bladed ram air units are used on all high performance aircraft. The units operate at 12,000 rpm which permits easy adaption to 400 cycle AC systems, as well as high hydraulic volumes and pressures with small pumps.



Cross section of four-bladed windmill for ram air turbine in Douglas in-flight refueling unit.



Emergency generator on A4D Skyhawk is "popped" into the air stream. Operable from 130 kts to Mach 1.4, the unit weighs 22 lb. Blade speed is controlled by a counterweight type governor.

Blade Governors

The secret to successful ram air accessories lies in the mechanism which governs the blade rotational speed. It must be light weight, simple, yet rugged enough to withstand the shock of sudden starting rotation, from 0 to 12,000 rpm in less than a second. Yet it must be sensitive enough to respond instantly to changes in air speed and load to keep the power output constant.

Two types of governors presently provide these capabilities. One type employs a blade counterweight to produce a net increase in pitch moment. Since this moment increases with rpm, the blades tend to rotate in the increase pitch direction. This results in an rpm reduction. The rpm droop is determined by an opposing speeder spring force scheduled through a linkage to the counterweight.

The other type, or spline governor, employs a flyweight splined to the blade axis. An increase in rpm causes the flyweights to swing outward on a mating spline attached to the blade root; this increases the blade pitch. The rpm droop is scheduled by a selected compression spring opposing the outward force of the flyweight.

The blade counterweight governor lends itself to two bladed high speed windmills, while the spline governor is better for the lower rpm type units such as the refueler.

Each blade has its own governor and they are coordinated through a linkage to keep all blades at the same pitch.

All parts are precision machined. Critical elements in manufacturing are the helical splines on the bore of the flyweight and the mating spline on the blade root sleeve. Other closely machined elements are the flyweights, blade root sleeves, and blade retaining bearings.

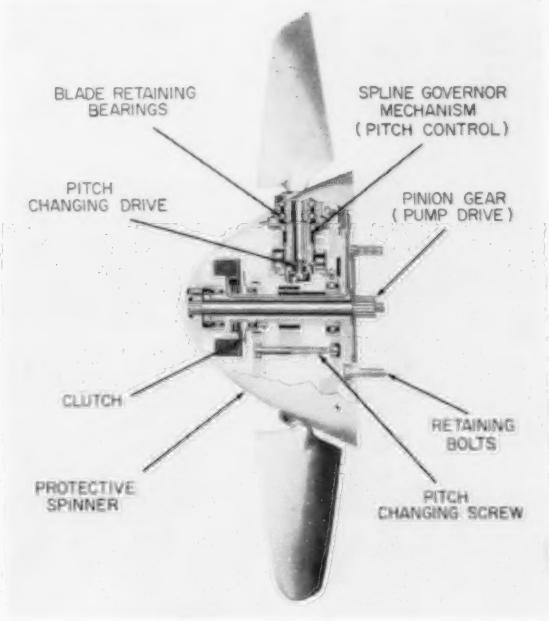
Bearing Problems

Naturally, the selection of the proper bearings for high speeds and severe environmental conditions is a critical point in the design of ram air turbines. However, the basic problem is not the speeds, friction or temperatures, it is contamination.

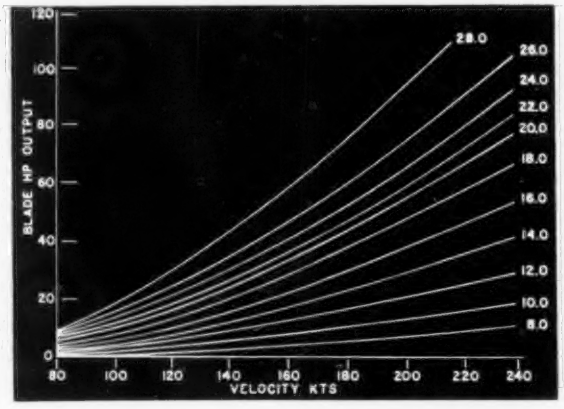
Bearings used are specially designed, totally enclosed and of stainless steel for corrosion resistance. Bearing sperators are of Nylon and lubrication is with baked-on Molykote.

In spite of all these precautions, dust and dirt can get into the bearings and shorten their life. This causes a great deal of trouble on the four-blade, 4000 rpm units, on which each blade retention bearing and the blade root mount, in order to retain accurate response between the governor and blade pitch changing mechanism.

Generator supplies 115/200 v, AC, at 400 cycles. Nominal speed is 12,000 rpm. Windmill has two blades.



Effect of horsepower for various windmill diameters.



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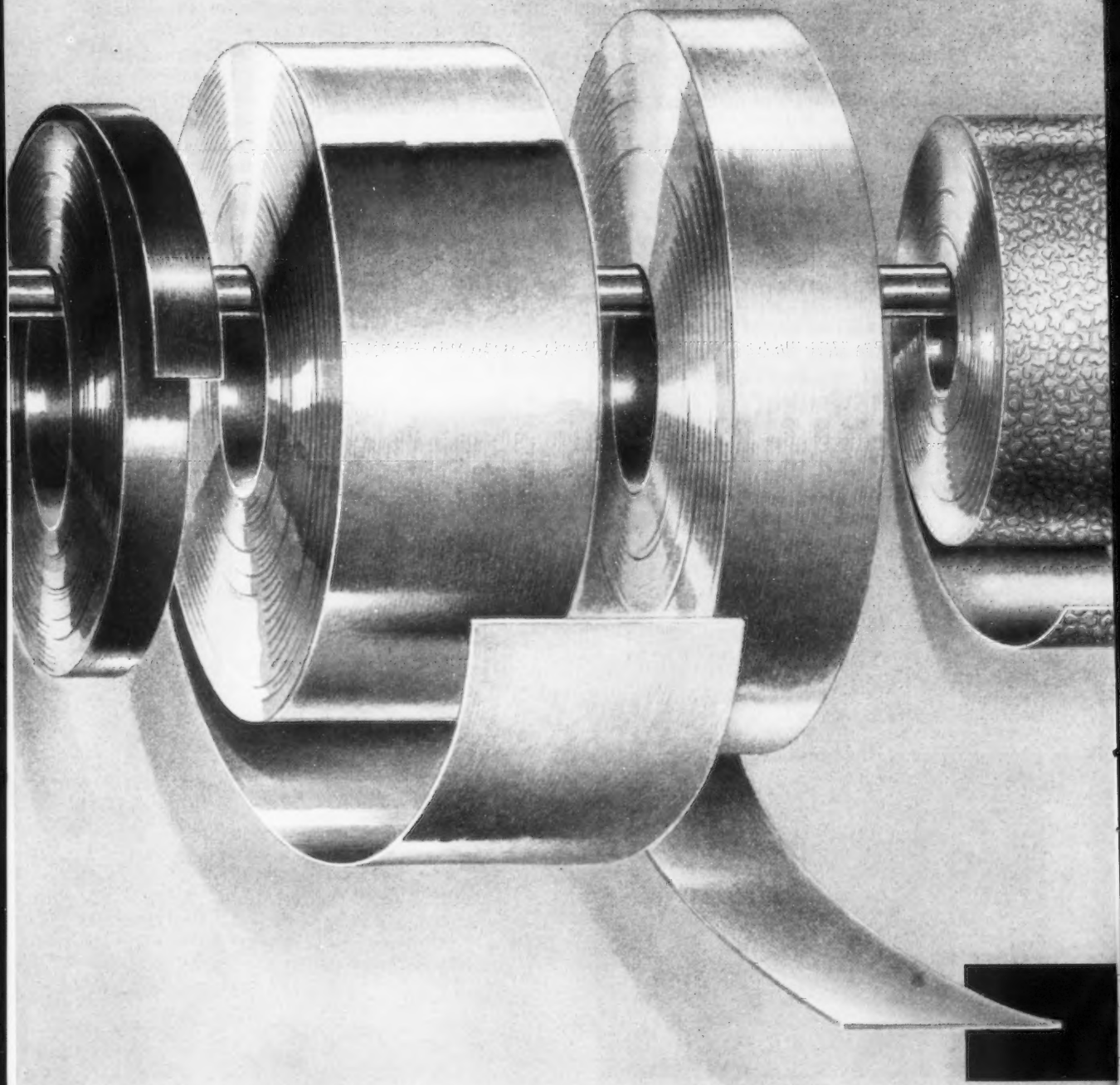

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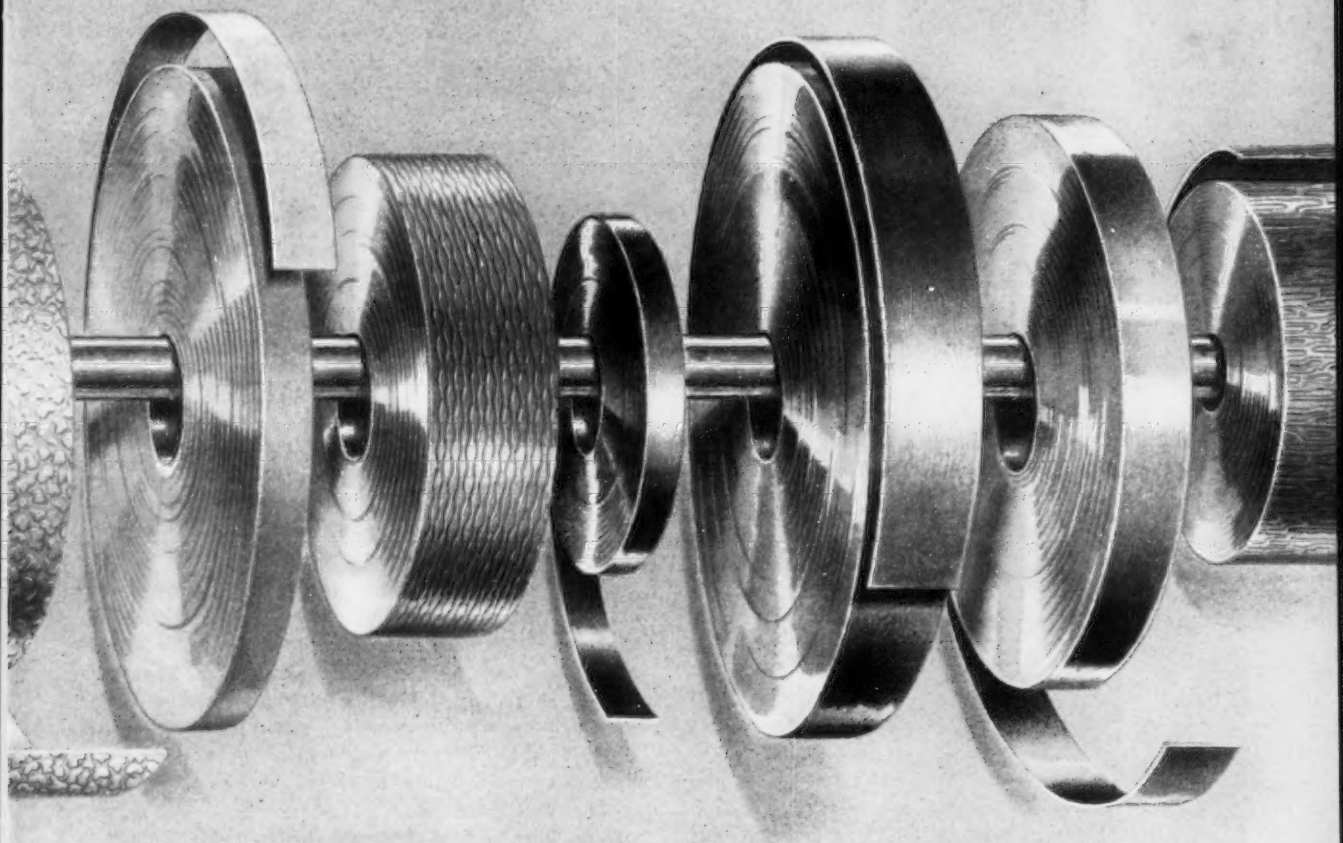

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convair delta fighter

wing-to-fuselage mounting is effected easily despite fourteen precision attachment points; adhesive bonding used in fuel cell

by Robert McLarren

Simplicity of structural design and ease of manufacturing the delta-wing aircraft configuration have been realized by Convair—San Diego in production of the Delta series fighters. (F-102A Delta Dagger, TF-102A combat trainer, F-106A Delta Dart, and F-106B two-seat interceptor.)

Unlike conventional aircraft, in which wing-fuselage mating requires essentially the attachment of two spar fittings to fuselage fittings, the delta configuration makes a large portion of the fuselage length a wing-fuselage joint. The Convair Delta series of fighters utilizes 14 separate bolt fittings to effect the mating. Design aspects of this major task have been so effectively handled that any wing panel of any Delta fighter can be field-installed to any fuselage with complete interchangeability.

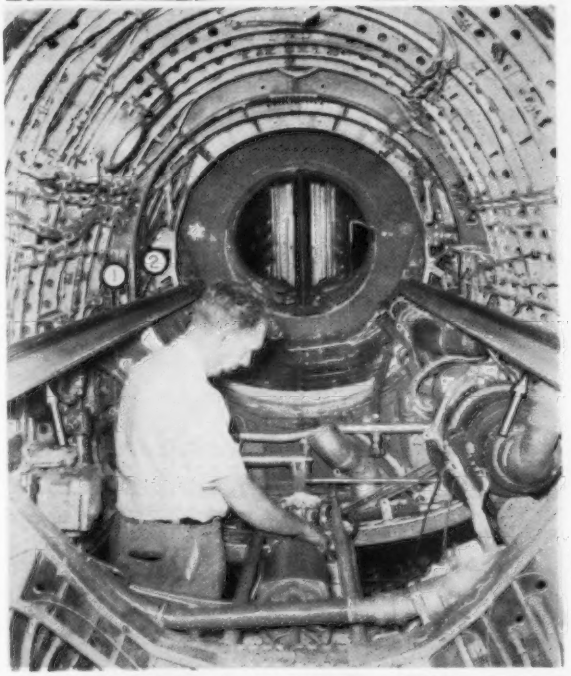
The tooling program for the F-102A fighter was initiated during the Korean conflict mobilization period, when "high-volume tooling for low-volume production" was the procurement policy. As a result, production rate of the Delta fighter series can be changed flexibly through the subtraction or addition of carriers on the mechanized production line.

Fuselage Made of Three "Barrel" Assemblies

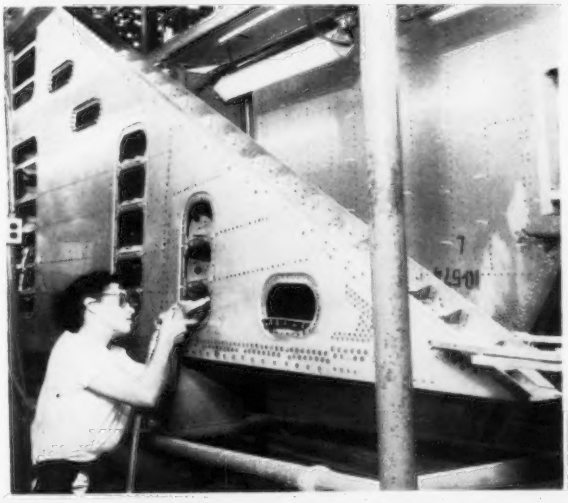
The function of the fuselage in the delta configuration is somewhat different from conventional aircraft in that it does not carry the usual empennage maneuvering loads, there being no horizontal stabilizer in the design. As a result, the Delta fuselage is basically an engine housing, and main fuselage frames serve primarily as wing spar carry-through structures. For these reasons,

Delta wing configuration makes a large portion of the fuselage length a wing-fuselage mating joint. Elevons along wing trailing edge move in unison as elevator, move differentially to provide aileron action. Note "area rule" fairings extending behind tail cone as "fix."

The fuselage consists of three major assemblies: pilot's compartment shown here is the most complex; it is mounted on a rotatable fixture to facilitate installation components.



View from aft end of fuselage shows engine "I" beam mounting rails (arrow), heavy press forging bulkheads 1 and 2, in the aft fuselage barrel. "Y" ducts of air inlet are visible in forward barrel.



Drilled wing skin is held in jig for rib drilling. Counterbored rivet hole in skin used as guide for drilling same hole pattern in ribs. After drilling, skin is removed from jig for Scotchweld tape application.

the Delta fuselage is made up of a series of transverse barrels.

The fuselage consists of three major assemblies: pilot's compartment, forward barrel and aft barrel. The most complex structural unit is the pilot's compartment. Built as an integral unit, it contains the cockpit, nose gear, and air inlets in a complex form of integrated elements. Most of this unit consists of a double skin in which the inboard panels function as the inner surface of the forward air scoops. This unit is built up from five sections: the pilot's firewall (aft of the cockpit), the pilot's floor, inboard pilot's panels (containing controls and electronics), forward air scoops and the forward radar compartment. After structural assembly, the completed pilot's compartment is placed on rotating fixtures to enable assemblers to rotate it to the most convenient angle for installation of equipment.

The aft fuselage barrel contains the fin and rudder, and the engine afterburner. The fin is an integral structural unit with the aft fuselage barrel, the latter is removable and replaceable for engine access. Five separate leading edge segments facilitate installation of electronic and pilot-static equipment in the fin. The vertical fin tip comprises a low-dielectric antenna, furnished complete by Goodyear Aircraft Corp.

The fuselage forward barrel contains the "Y" ducts which converge from separate inlets into a common inlet for the engine compressor. The complex form of these ducts, plus the requirement for high rigidity under load, necessitates

convair delta fighter

continued

that they be fabricated from sheet metal. Frame spacing is only four in. in portions of this compound-formed ducting.

The Pratt & Whitney J57 engine is installed in the fuselage aft barrel from the rear and is supported on heavy "I" channels. It is moved forward into final position on rollers along the channels.

Area Rule "Fix"

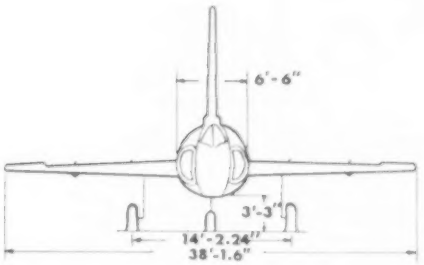
Since the F-102A was already tooled up at the time of the area rule discovery, this important aerodynamic fuselage shaping principle was adapted to the airplane by the addition of "coke bottle" fairing assemblies on the tail cones. This "fix" enabled the airplane to continue in uninterrupted production while utilizing the discovery. The new F-106A model comprises an entirely new fuselage faired completely according to area rule principles and, therefore, renders these tail cone fairing units unnecessary.

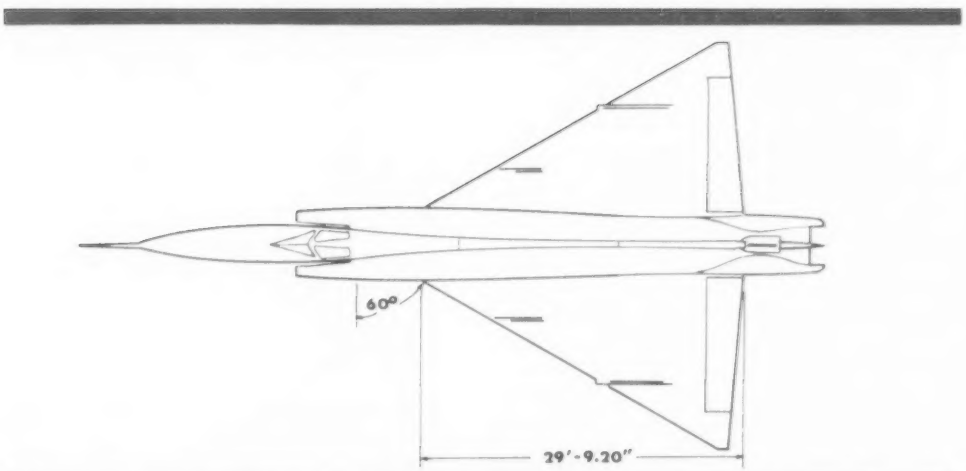
Wing Comprised of Five Spar Forgings

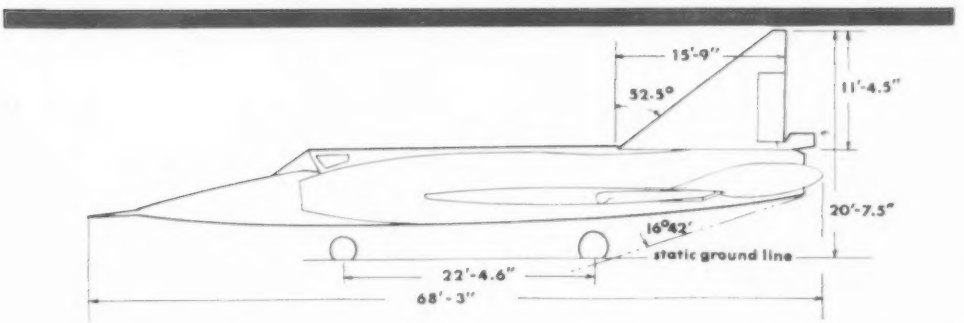
The delta-wing planform inherently promotes an efficient structure through virtually ideal load distribution. The Delta wings are made up of five spar assemblies, each longer than the proceeding one aft from the apex; the longest being only 11 ft. These spars are heavy forgings, and together with the main fuselage bulkheads,

SPECIFICATIONS FOR CONVAIR DELTA AIRCRAFT

Model	Engine	Span		Length		Height		Description
		ft	in	ft	in	ft	in	
F-102A	P&W J57-P-23	38	1½	68	3¼	20	7½	Delta Dagger Interceptor
TF-102A	P&W J57-P-23	38	1½	63	4¼	20	7½	Two-seat Combat Trainer
F-106A	P&W J75	38	10	70	1½	19	10	Delta Dart Interceptor
F-106B	P&W J75	38	10	73	8	19	10	Two-seat Interceptor







are the first products of the Air Force "heavy press program."

The primary wing is assembled from five lateral structural segments: forward wing, forward tank, landing gear, aft tank and trailing edge subassemblies.

Each wing segment is plated with a single, large wing skin. These skins are sculpture-milled 7075ST-T6 aluminum alloy tapered from 0.375 in. at the root to 0.040 in. at the tip.

The wing leading edge is assembled from six separate units. This breakdown of the leading edge facilitates the forming of the leading edge camber, which progresses from root to tip. The tip unit also features a complex aerodynamic shape to accommodate the spanwise-flow aerodynamic problem of the delta planform.

Adhesive Bonding in Fuel Tanks Sealing

The integral wing fuel tank assemblies of the Delta fighter wings utilize faying surface sealing. Convair's adhesive bonding program has resulted in the development of Scotchweld, a rolled-tape nitrile rubber phenolic adhesive with a polyethylene film produced by Minnesota Mining & Manufacturing Co. to Convair specifications (AMM, January, 1958).

Proper preparation of the faying metal surfaces is the key to successful bonding. Convair utilizes the Alodine 600 system in which the metal is given five separate dips to provide both metal cleaning and corrosion protection. On the final dip the metal is water-rinsed and dried. Scotchweld adhesive primer is then sprayed on to a thickness of 0.001 in. This primer is oven dried and the treated parts are placed in an assembly jig. The

Aircraft move in unorthodox side-by-side fashion along final assembly bay. Functional equipment, powerplant and radome units are installed in final assembly. Over 35 production F-102A fighters are visible in both bays.

Riveting of aft fuel tank assembly after application of Sotchweld tape, is accomplished in this rotatable, castored jig. Tank section is subsequently placed in an electric oven at 320° F for one hour to cure the adhesive and effect a bond.

Completed wing structures receive functional parts installation as they progress along rail. Wing is complete throughout prior to mating with fuselage.

convair delta fighter

continued

parts are drilled for riveting and the Scotchweld tape is applied along the desired sealing surfaces. The skin plates are then placed over the sturcture and the assembly is riveted.

Following riveting, the entire tank section is placed in an oven and the adhesive cured at 320°F. for one hour. Completed tanks are pressure tested to 20 psi.

After assembly of the structural primary wing, it is placed on a mechanized line and main landing gear, elevons and associated controls, fuel lines, wing fences, and electrical items are installed. The wing is a complete unit at the time of its mating with the fuselage.

The wing-fuselage mating, requiring the precision fit of 14 bolts, is accomplished without reaming. This achievement is made possible by the use of simulated fuselage fittings as major indexing and tie-down fixtures in all wing subassembly jigs, and simulated wing fittings in all fuselage subassembly jigs. In this manner, tolerances are prevented from accumulating.

Final Assembly

Final assembly of the airplane consists primarily of installation of functional equipment, and system checks. Contrasting with conventional aircraft, the last major item to go into the Delta fighter is the engine. This stems from the virtually independent component nature of the powerplant. The engine is mated with the afterburner and associated controls and moved to the test cell for preliminary running. It is then returned to the factory, where the required shrouds and seals are installed and the control systems checked for continuity. The complete powerplant is then moved to the final assembly line and inserted into the rails of the airplane and secured. Hookup of required controls and plumbing completes the installation.

Final item of assembly is the radome. The completed airplane is then moved to the paint shop and subsequently flight delivered to the Convair facility at Palmdale, Calif., where combat equipment is installed and required predelivery flight time accumulated.

Subcontracting

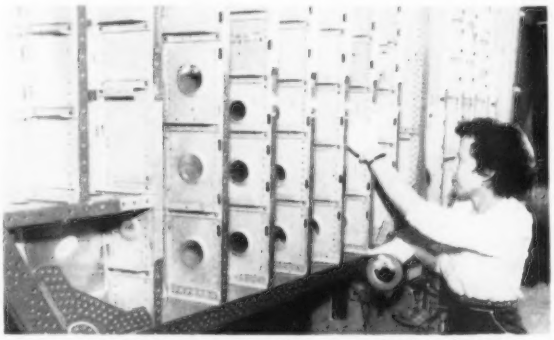
Extensive portions of the Delta-series fighters are provided by subcontractors.

Metlbond parts and processes, licensed to Narmco Resins & Coatings Co., are provided by both Convair and subcontractors, these include wing tips by Thermo-Form Co., wing fence assemblies by AVCO Manufacturing Corp., and elevons, rudder and a variety of doors by Convair-Fort Worth. These sandwich structures are built up of thin skin, bonded to a thick honeycomb core. (AMM, March, 1958.)

Other major subcontractors include Rheem Manufacturing Co. (tail cone), Goodyear Aircraft Corp. (canopy, fin tip and windshield assemblies), and Zenith Plastics Co. (radome).

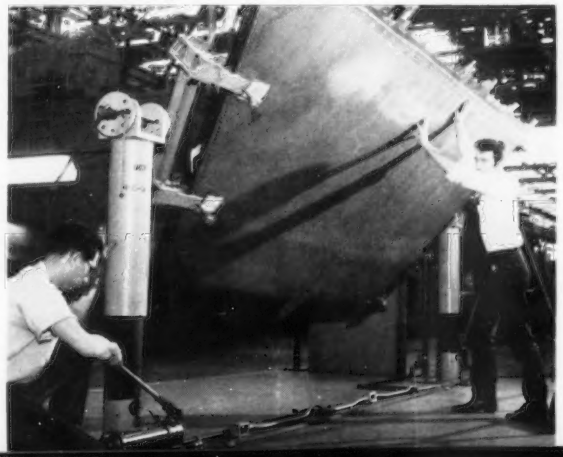
F-106 Production

The new F-106A Delta Dart and F-106B two seat interceptor are now in initial production stages on their own separate manufacturing lines. The decision to create an entirely separate assembly operation for this new airplane was prompted by the rather complete change in the fuselage design. Major changes include a larger diameter to accommodate the huge Pratt & Whitney J75 engine and "area rule" incorporation. The air inlets are moved aft to the vicinity of the wing leading edge with associated removal of the complex ducting from the pilot's compartment assembly. These major changes rendered the F-102A tooling unusable on the new airplane.



Scotchweld adhesive bonding tape is applied to faying surfaces of wing fuel-tank structure, previously been treated by Alodine 600 process for cleaning and corrosion resistance. Workers wear clean white cotton gloves.

Sealed tank section is pressure tested at 20 psi in this rotatable jig fixture. Hydraulic pump (lower left) raises both stands to height permitting 180-deg. rotation of wing. Padded clamps hold wing without scratching.



welding, brazing, and chemical milling are major fabrication techniques in stainless steel research vehicle

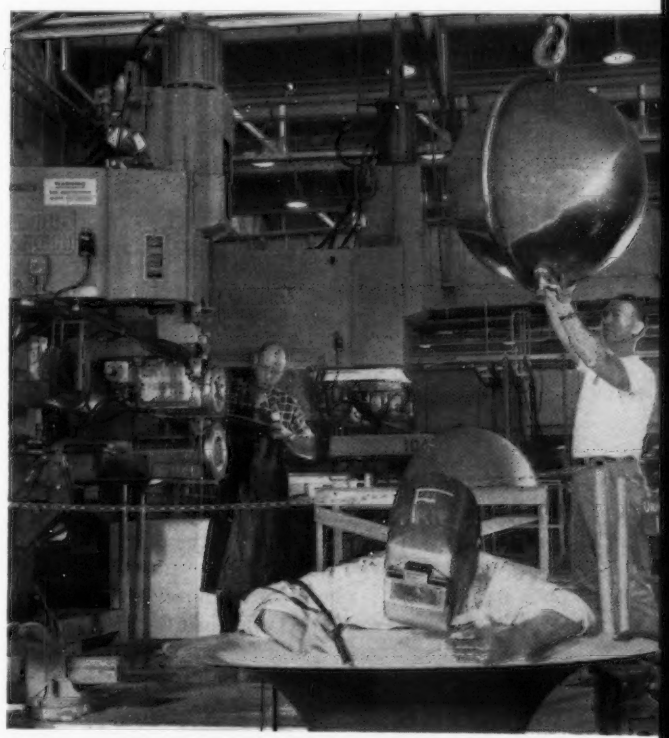
X-15 manned-satellite testbed

When the first of three proposed North American X-15 stainless-steel manned space and reentry research vehicles soars out of the earth's atmosphere seeking its 3,500 mph and 100 mi speed and altitude goals, it will leave behind the era of aluminum skins and mechanical fasteners common to airframe fabrication since the first metal aircraft.

Rolled stainless steel, reportedly of the precipitation hardened, semi-austenitic type, is being stretch-formed and subsequently integrally stiffened by chemical milling in the manufacture of the fuselage side panels. Joining of airframe components is effected largely by welding, about 65 percent of all structural jointures being fusion or resistance welded. The entire fuselage skin and wing surface are stainless steel to cope with the heat environment on reentry.

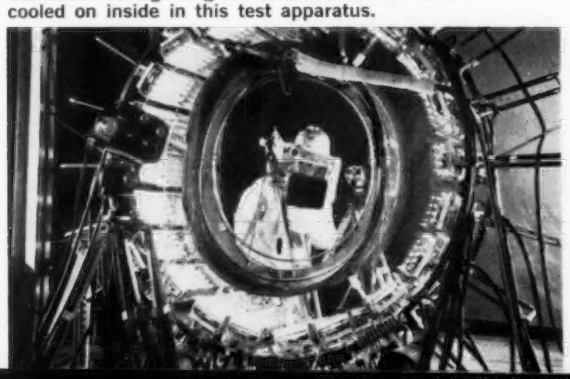
Threaded fasteners have also been designed out of the hydraulic system to reduce the possibility of leaks occurring after repeated mechanical and thermal shock. Brazing is used to "permanently" seal tubing in place.

There has been some unofficial speculation that X-15 will become the first manned satellite. In its present configuration it does not possess enough power to achieve orbit however, altitudes of 400 mi are programmed for late test stages.



Spherical stainless steel pressure vessel for rocket's fuel system shown being moved from welding area. Welder in foreground is connecting other fuel system components.

Rigorous environmental testing is done on each X15 component to enhance reliability. Stainless fuselage ring is heated on outside and cooled on inside in this test apparatus.



Fuselage sections are assembled on huge welding fixtures. Approximately 65 per cent of all structural jointures are welded.

estimating missile proportions

empirical process provides rapid qualitative information for preliminary design

by Dr. Saxe Dobrin

The chief problems concerning manned space flight are not those of engineering design, but rather of systems operation. For large payloads and high terminal velocities, entirely new concepts are required. To arrive at an optimum plan of operation, the entire system must be considered. This involves not only technical matters, but law and finance; plus the use of resources, energy and human talents. The very best propulsion characteristics are desired, but these might be compromised in favor of a more manageable system.

Overall design will probably be established by the propulsion means. Features of the missile affect the choice of flight path and the flight path influences the choice of design features. The relationships between the missile's flight position and the corresponding acceleration and velocity are overwhelmingly complicated. Although precise computations can be made with electronic computing machinery, the effort is not only burdensome but inappropriate for preliminary planning. It is far more beneficial to use an estimating process which, if not precise, will at least provide qualitative information quickly.

The simplest method is to express the features of the missile in terms of its gross weight. The accompanying tables and figures serve as a ready reference for practical engineering information. With them, a designer can survey a number of different arrangements and arrive at a missile design which fits the intended purpose.

Having established an appropriate terminal velocity for the mission, one can choose the number of stages, the mass ratio of each stage, and the specific impulse of each stage in keeping with practical engineering considerations.

Table 1 gives appropriate velocity requirements for some representative missions. These values include the ideal velocity plus an amount which allows for retardation due to gravity and drag.

Of the two retarding effects, gravity is usually the more significant. Its affect is as a function of the burning time and the missile flight path angle relative to the earth's surface.

In practical missile designs, long burning time is generally associated with high specific impulse. This, in turn, increases the retardation effect of gravity and partly counteracts the gain due to specific impulse. Table 1 is oversimplified for any purpose except for estimates, but it does serve to indicate how velocity, specific impulse, and burning time are related. The correction for drag and gravity is on the order of a few thousand feet per second, nominally 4000 fps for solids, 5000 fps for liquid propellant, and 7000 fps for nuclear propulsion.

TABLE I

Combined Velocity Requirement For Typical Advanced Missions

(The "combined velocity requirement" is the required terminal velocity, plus an added amount to compensate for drag and gravity).

Mission	Combined Velocity Requirement Ft/Sec Solid Propellant	Liquid Propellant	Nuclear System
5000-Mile Ballistic Missile	26,000	27,000	29,000
Satellite (300-Mile Altitude)	30,000	31,000	33,000
Moon Reconnaissance	42,000	43,000	45,000
Mars Reconnaissance	43,000	44,000	46,000

TABLE V

Definition of Algebraic Symbols

a = Ratio of first to third stage specific impulse.
b = Ratio of second to third stage specific impulse.
d = shell diameter, inches.
g = gravitational constant, 32.2 ft. per sec^2
Isp = specific impulse of propellant lb.-sec. per lb.
p = chamber pressure, lb. per sq in.
R = mass ratio [ln R = logarithm of mass ratio]
S = stress, lb. per sq in.
t = metal wall thickness, in.
Δv = small change in velocity, ft per sec
Δv (gravity) = small change in velocity due to gravity effect, ft per sec
Δv (drag) = small change in velocity due to drag, ft per sec
v^* = combined velocity requirement, ft per sec

More properly, the velocity must be calculated instant by instant from the equation:

$$\Delta v = I_{sp}\, g\, (\ln R) - \Delta v\ (\text{gravity}) - \Delta v\ (\text{drag}) \qquad (1)$$

Symbols are defined in Table 5. By combining all velocity terms into one, as has been done for Table 1, the equation is simplified to

$$v^* = (I_{sp})\ (g)\ (\ln R) \qquad (2)$$

Multi-Stage Missiles

For multi-stage missiles, it is necessary to interpret both the specific impulse and mass-ratio terms very carefully. Equation (1) can also be written as

$$v^* = v_1 + v_2 + v_3 = I_{sp}\ (g)\ \ln R_1{}^a\, R_2{}^b\, R_3 \qquad (3)$$

In this equation, v_1, v_2, and v_3 are the velocities added by each of the three stages. The indexes, a and b, allow for propellants with different specific impulses if desired. The mass ratio of each stage, R_1, R_2, and R_3, takes account of the weight of each subsequent stage. Similar equations would be written for two, four or more stages.

Ideally, the highest velocity can be attained if v_1, v_2, and v_3 are equal (or if the propellant for each stage has a different specific impulse, if $R_1{}^a = R_2{}^b = R_3$). However, other arrangements are nearly as satisfactory and may be more beneficial from the standpoint of practical engineering design. For any missile using combustion propellants and carrying a reasonable payload, the velocity per stage should not be more than 15,000 to 10,000 fps; less would be preferable. For advanced types of propulsion using nuclear energy to get high specific impulse, single-stage velocities of 20,000 to 40,000 pfs might be considered.

As a starting point for design, the number of stages must be selected and the desired total velocity divided among the stages. Selection of propellants must also be made. The mass ratios for each stage can then be calculated. Starting with the last stage, the weights of its gross features are estimated, their total then being the payload of the next-to-the-last stage. Similarly, the next-to-the-last stage is calculated, and ultimately the gross weight of the missile is determined.

In the last stage, or in any stage, the major elements are the useful payload, the guidance equipment, directional control equipment, propellant tanks and body structure, rocket engine and propellant.

Within the total weight allotted for one stage, the weights of each element can be altered by successive calculations, a satisfactory combination can be chosen. The mass ratio of the stage will be:

$$R = \frac{W_p + W_L + W_g + W_c + W_t + W_e}{W_L + W_g + W_c + W_t + W_e} \qquad (4)$$

where the subscripts p, L, g, c, t and e correspond to propellant, useful load, guidance, controls, tanks, and engines. Also,

$$R = \frac{G}{G - W_p}$$

TABLE II

Properties of Propellants for Preliminary Estimating Purposes

Propellant System	Mixture Ratio	Specific Impulse (sec) of Booster Rising out of Earth's Atmosphere	Specific Impulse (sec) for Propulsion in Space	Bulk Density, lb/ft³
Hydrogen Peroxide—Alcohol (92.5%)	4.0	266 avg	291	77.5
Hydrogen Peroxide—Jet Fuel	6.5	270 avg	296	80.0
Hydrogen Peroxide—Hydrazine	1.7	286 avg	312	77.5
Nitric Acid—Unsymmetrical—Dimethyl hydrazine	2.6	272 avg	298	76.8
Fluorine—Hydrazine	2.0	343 avg	368	83.0
Oxygen—Jet Fuel	2.25	285 avg	311	77.5
Oxygen—Hydrazine	0.75	306 avg	332	78
Oxygen—Alcohol (92.5%)	1.5	276 avg	301	75.5
Ammonia, Heated to 4500° F	—	381 avg	411	42.5
Hydrogen, Heated to 2500° F	—	575 avg	628	4.4
Hydrogen, Heated to 4500° F	—	750 avg	840	4.4
Solid Propellant*	—	220 avg	250	80*

* A typical propellant with a loading fraction of 0.79.

Propellants

Numerous chemical combinations can be considered as rocket propellants. For practical reasons, however, the choices are limited to only a few oxidizers and fuels. Table 2 gives examples of some combinations.

The specific impulse of a propellant combination is primarily a property of its chemical constituents, but it also depends somewhat on the thrust chamber design of the rocket engine and the atmospheric pressure in which the engine

estimating missile proportions

continued

operates. Aside from specific impulse, the important criteria for propellant selection are: storability, handling hazards, ignition characteristics, industrial availability, heat transfer characteristics, useful temperature range, and effect on materials.

For a rocket engine that will operate outside the earth's atmosphere, it is desirable to use an expansion ratio between 15 and 25 to 1. Nozzles with very large expansion ratios can be built, but the added weight of the nozzle cone and the problem of keeping it cool would cancel any real gain in specific impulse. Table 2 gives an indication of the difference in specific impulse with a large expansion area ratio at high altitude and a smaller one for atmospheric operation. In the earth's atmosphere, there will be a region where they will be underexpanded and another where they will be overexpanded. The proper choice of an expansion cone will depend upon the specific flight conditions. Specific impulse values in Table 2 represent overall average values for booster engines with area ratios of 8 to 1.

Useful Payload

The useful payload for a manned earth-circling rocket might weigh 20,000 lb. It would include, in addition to a man and provisions, instruments to collect information as it made its journey, wings, parachutes and retarder rockets to bring it safely back to earth, a power supply and a transmitter to maintain communication with ground bases. A sounding rocket to reach to the moon might have a 500-lb payload with power supplies and transmitters, or it might carry a visible flare to signal its arrival. It would need tiny jets to adjust for inaccuracies along its free flight path and sensing elements, with computers to call for corrections.

Guidance and Control Equipment

During its period of powered flight, the rocket will be deviated from its intended path for a variety of minor reasons. These deviations must be compensated by directing jet forces sidewards. This can be done by vanes in the jet stream, by motion of the main thrust chambers or by auxiliary jets. The deviations of several stages might be accumulated for one final adjustment in the last stage just prior to burnout. This would simplify the requirements for control equipment but would be very costly in terms of extra propellant. The more economical arrangement (in terms of weight and size) is to steer each stage along its intended path. This requires directional control equipment for each stage.

For simplicity, directional control devices can be considered as being 0.1 to 0.5 per cent of the gross weight of each stage.

Although each stage might have its own directional control equipment, one set of electronic guidance apparatus in the final stage might serve the entire system. This might reduce the total weight of electronic equipment but at the same time increase the weight carried by the final stage. For this added weight, the previous stages might become disproportionately large. The weight of airborne guidance equipment and directional controls must therefore be proportioned to get the best overall results.

The "brains" of the missile might weigh as little as 50 or as much as 5000 lb. Unfortunately, the weight of the brains will not be in proportion to the size of the missile but rather in proportion to the type of information it must handle to get the desired accuracy. The weight will also depend upon the scientific skill that can be employed in getting small devices to do complicated tasks.

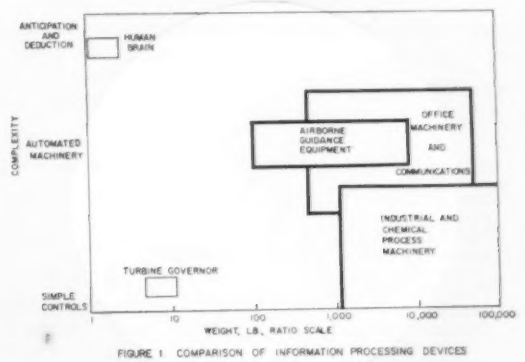


FIGURE 1. COMPARISON OF INFORMATION PROCESSING DEVICES

In one decade electronic data processing machinery has been reduced from huge racks of vacuum tubes to printed circuits with tiny transistors. The eventual lower limit will be a device as compact yet as resourceful as the human brain.

Figure 1 suggests the weight that might be allotted for a missile's data processing system. A nominal weight of 1000 lb can be used as a starting point, later to be adjusted upward or downward.

Tanks and Body Structure

Table III shows how the basic criteria of internal pressure, size and stress loading will affect the weight of the missile structure. Fundamentally, the size of each stage depends upon the amount of propellant it must carry and the pro-

TABLE III

Tanks and Structure Weight, lb per cu ft of Contents

	Conservative	Optimistic
Solid Propellant		
small (1–3 ft diam)	20	5
medium (3–5 ft diam)	15	5
large (5–25 ft diam)	15	5
Pressure-Fed Liquid		
small (1–3 ft diam)	15	5
medium (3–5 ft diam)	15	5
large (5–25 ft diam)	—	—
Pump-Fed Liquid		
small (1–3 ft diam)	5.0	2.0
medium (3–5 ft diam)	3.0	1.0
large (5–25 ft diam)	2.0	0.5

pellant density. A small structure necessarily will have a higher weight per unit volume than a larger structure of similar design, since the exterior surface varies inversely with the volume of propellant. Table III shows the specific weights which are within the realm of practicality.

A dominating factor for solid propellant and pressure-fed liquid propellant systems is the wall thickness to withstand internal pressure. In general, it is desirable to operate with tank pressures of 300 psi minimum. An appropriate wall thickness can be usually estimated by the familiar formula for hoop stress:

$$t = \frac{pd}{2s}$$

Rocket Engines and Nozzles

Weight-wise, an important item of the engine is its nozzle cone. For a solid propellant thrust unit, no other elements are needed. For liquid propellants, the engine must also include a propellant injector, control valves and ducts, the pumps and their turbine drive.

So many design variations are possible that any reliable weight estimating procedure is complicated. However, for purposes of surveying competitive missile systems, Figures 2 and 3 provide a guide to engine weight in terms of thrust.

For liquid propellants, a thrust of 1.25 to 2.0 times the gross weight of the stage is used. Solid propellant rockets, with shorter burning times, will be designed with a ratio of thrust to weight of 3.0 to 6.0 or even higher.

Examples of Calculations

As an example of the process for estimating the gross features of a missile, we might consider a proposal to place a 10,000-lb body in an orbit 300 miles above the earth.

Arbitrarily, we will choose a propulsion system as follows: The first stage will use pump fed liquid oxygen and jet fuel, to give the missile approximately 30 per cent of its design burnout velocity. The second stage will use nitric acid and unsymmetrical dimethyl hydrazine, also pump fed, to give another 30 per cent of the velocity; the final stage will be solid propellant to give the remaining 40 per cent. The first stage will operate in the atmosphere and will have an expansion ratio of 8 to 1, the others will have an expansion area ratio of 20 to 1.

Since the propulsion system is a combination of solid and liquid propellant, the required burnout velocity, according to Table I, will be between 30,000 and 31,000 fps. Arbitrarily a value of 30,500 fps is used. The corresponding velocity increments are listed in Table IV as calculated from equations (1) and (2).

Let us imagine the third stage as being approximately 100,000 lb. Of this, 10,000 lb is useful payload. From equation (5) we calculate that for a mass ratio of 4.57 the propellant weight

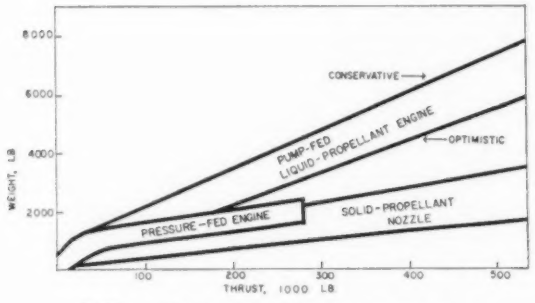


FIGURE 2. ESTIMATED ENGINE WEIGHT, 8:1 AREA RATIO FOR ATMOSPHERIC OPERATION

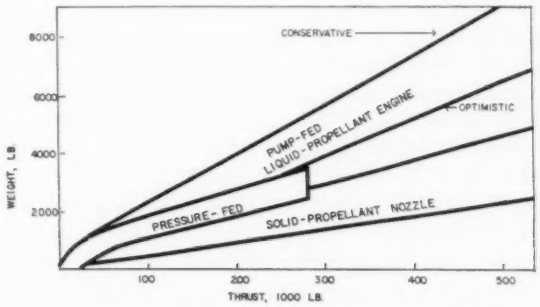


FIGURE 3. ESTIMATED ENGINE WEIGHT, 20:1 AREA RATIO FOR HIGH-ALTITUDE OPERATION

is 78,000 lb. The remaining 12,000 lb is available for guidance, controls, motor case (or tank weight) and nozzle weight. If we assume, optimistically, that the solid propellant burning time can be 60 sec, the average thrust will be:

$$\frac{78{,}000 \times 250}{60} = 325{,}000 \text{ lb}$$

or about 3.25 times the weight of the third stage. A nozzle for a thrust unit of this size will be about 1200 lb (see Fig. 3). The volume of the motor case will be about

$$\frac{78{,}000 \text{ lb propellant}}{80 \text{ lb/cu ft}} = 975 \text{ cu ft}$$

TABLE IV

Mass Ratios for Three Stages of A Proposed Satellite Missile

Stage	Propellant	Specific Impulses, Sec.	Velocity Increment Ft/Sec	Mass Ratio
1	Oxygen – Jet Fuel....	285	9230	2.74
2	Nitric Acid – UDMH..	298	9230	3.62
3	Solid Propellant.....	250	12,200	4.57

Using Table III we estimate the propellant chamber will weigh about 8 lb/cu ft or a total of 7800 lb. This leaves 3000 lb available for guidance, controls and residual propellant.

After successive trials, we assume for the second stage a gross weight of 300,000 lb, of which 100,000 lb is the third stage. The second stage propellant weight is calculated (equation 5) to be 186,000 lb for a mass ratio of 2.62. The propellant will occupy 2420 cu ft for which a structure at 2 lb/cu ft will weigh about 7000 lb. Directional control equipment at 0.3 per cent will weigh about 1000 lb.

The total for the second stage is

Useful load (i.e. third stage)	100,000 lb
Propellant	186,000
Pump fed engine	7,000
Structure	5,000
Directional controls	1,000
	299,000 lb

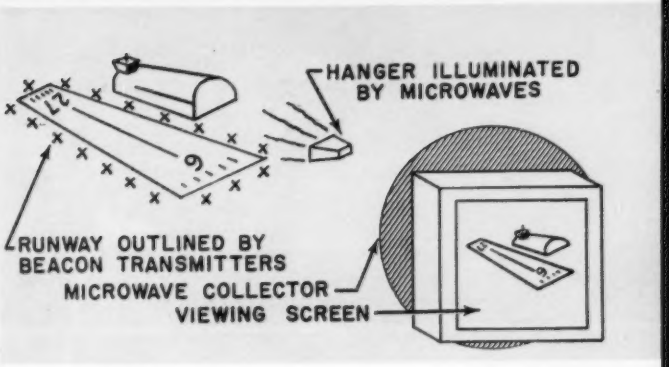
This is close to the value of 300,000 lb which was first assumed.

In a similar fashion we assume the gross weight of the first stage to be 930,000 lb of which 300,000 lb is the combined weight of the second and third stages and 592,000 lb is the weight of propellant for the mass ratio 2.74. This amount of propellant requires a structure with 7400 cu ft internal volume which, at 2 lb/cu ft, will weigh about 15,000 lb. For an engine with a thrust of 1.5 x 930,000=1,400,000 lb, the engine will weigh about 18,000 lb. Along with 3000 lb for directional control equipment, the total weight of the missile will be:

Useful load (second and third stage)	300,000 lb
Propellant	592,000
Engine	18,000
Structure	15,000
Directional control equipment	3,000
	928,000 lb

Obviously there are many adjustments which can be made at each step in the calculations. The significant items are those which affect the ratios of weights between successive stages.

As calculated in this example, a missile with a gross weight of 930,000 lb must be used to deliver the 10,000 lb payload to its intended orbit. Of this gross weight, 836,000 lb (or 90 per cent) is propellant, 84,000 lb (or 9 per cent) is propulsion apparatus, structure, directional controls and guidance, and one per cent is payload.



eyetron

Converts Microwave Radio Energy into Visible Light

Aviators may soon have an additional instrument to cope with zero-visibility conditions. Called Eyetron because it functions somewhat like the human eye, this device developed by the Diamond Antenna and Microwave Corp. of Wakefield, Mass., is sensitive to microwave energy, and produces on a screen a picture of scenes illuminated by a source of microwave radiation. The picture appears on the screen instantaneously and continuously so that it corresponds in all respects to the appearance of the scene to the human eye. It provides vision at times when normal vision is obscured by fog, smoke, haze, or other conditions opaque to visible light but transparent to microwave energy.

How It Works

The accompanying diagram illustrates how the system works. It consists of the following: a microwave collector which separates incoming waves according to their angle of arrival, channeling all waves from a given direction into a precise location corresponding to that direction; an electronic circuit which senses the presence or absence of waves arriving from a particular direction; and a viewing screen which displays in an appropriate location a spot of light for each direction from which microwave energy is received.

The diagram illustrates how the system would be utilized to "see" an airport runway. The runway would be outlined by a series of beacon transmitters in the same manner that runways are now outlined by marker lights. Obstructions, such as hangers, could be illuminated by a microwave antenna in the same manner that they are now illuminated by flood lights. The receiving unit "sees" the beacon transmitters as well as the energy reflected from the obstruction and shows on the screen a true perspective picture of the scene.

Not Radar

The Eyetron principle is not similar to that of radar. In comparison, it is reported as considerably simpler. The differences, both in principle and application, are as follows: radar sends out a pulse of energy in a particular direction and waits for echoes to return from objects in this direction; it has a minimum range since the receiver cannot operate while the transmitter is on; if more than one direction is of interest, the radar must scan, examining directions in time sequence. Various displays are used to present the information which the radar obtains, but these are unnatural and require a certain amount of interpretation by skilled operators.

The eyetron looks simultaneously at all directions in its field of view without scanning, and displays images simultaneously of all objects in the field of view. It has no minimum range. The presentation is a true perspective of the scene, requiring no interpretation. The system is passive; the source of microwave radiation originating from one or more sets of auxiliary equipment. There can be no interference between several receiving sets operating in the same area as there would be in congestion of radar sets.

Potential Applications

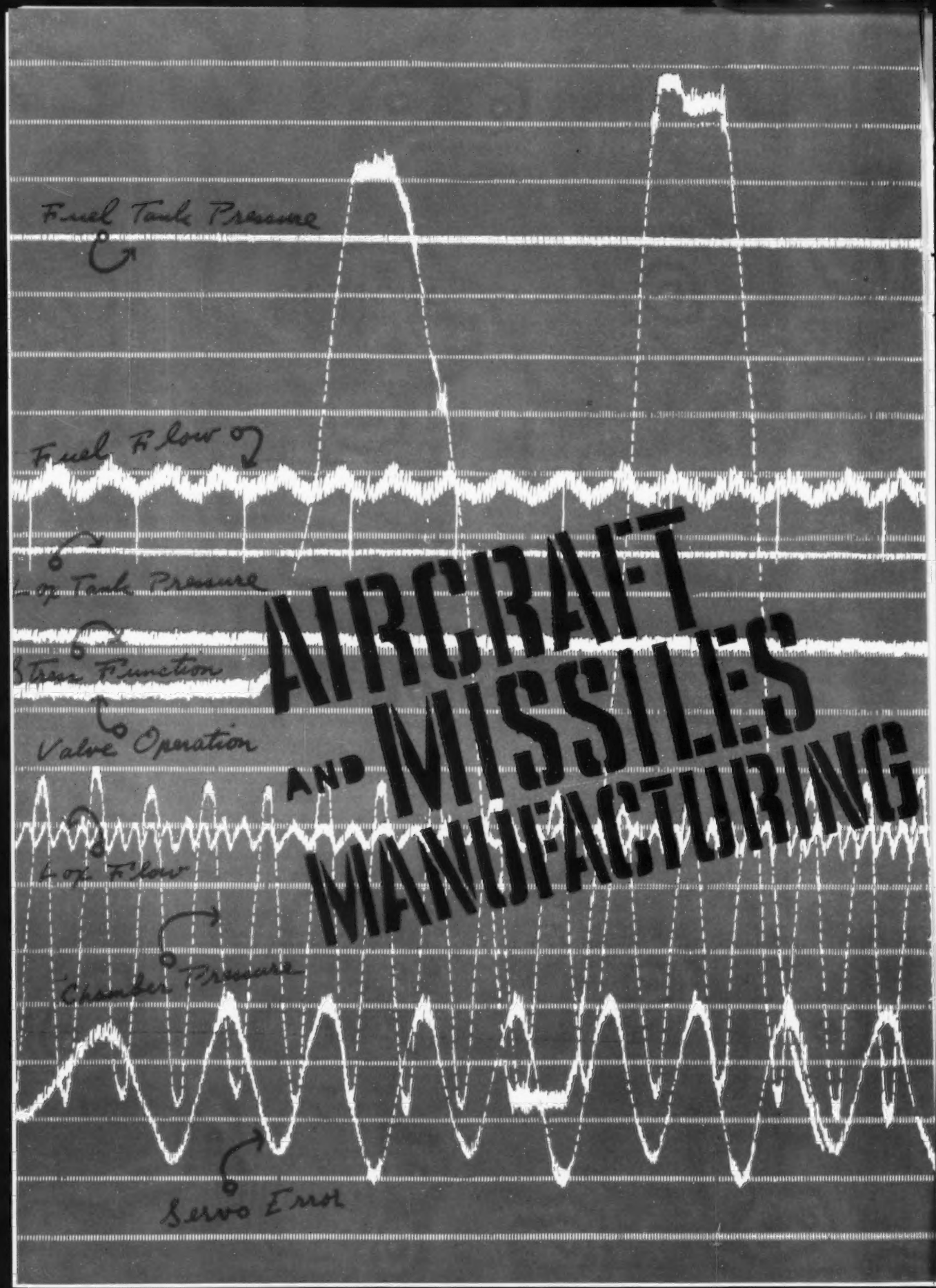
The concept employed on the transmitted energy enables the use of extremely narrow-band, high-sensitivity circuitry. Projected models, presently under development, will be constructed in extremely miniaturized versions using low-power transistors so that the electronics necessary for a chosen number of picture elements will be packaged in a compact volume and will operate at a small fraction of the power required for radar.

Furthermore, the device may be so constructed as to be selectively sensitive at several frequencies in such a manner as to visually display different colors on the viewing screen. In addition, MTI (moving target indication) can be incorporated in the device by relatively simple circuitry changes, as compared to radar.

This system, which promotes visibility by converting microwave radio-energy into visible light, is not intended to duplicate function of nor replace radar; it is rather aimed to provide the "missing link" for navigation through the marginal minimum-radar-range conditions.

Of the many possible applications of this system the following immediate ones have aroused specific interest.

- airport landings (military & commercial)
- navy aircraft carrier landings
- air traffic control
- airport surveillance
- anti-collision (air and sea)
- missile or rocket tracking
- coastal defense early warning systems
- low flying aircraft detection



AIRCRAFT AND MISSILES MANUFACTURING

BY JUPITER, IT'S TALKING BACK!

Miles high in the sky, missiles are talking back—
telling the men responsible for their design, production
and flight exactly what it's like out of this world.

And missile men are talking back to AMM . . .

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An 8 channel oscillograph trace recorded, ready to read instantly upon blast-off. Supplied from equipment manufactured by Consolidated Avionics Corporation.

AIRCRAFT AND MISSILES MANUFACTURING

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Wiring harness being installed on ground-support amplifier assemblies.

Ground support computer console chassis is held on universal type fixture for accessibility during manufacture.

Thor's brains

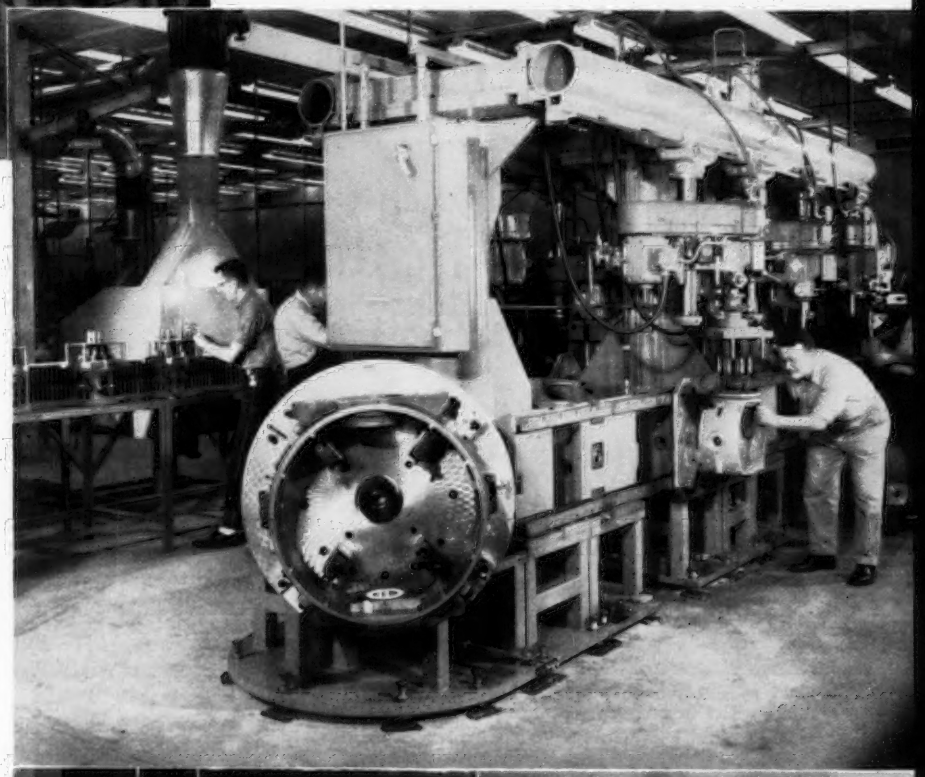
require millionths-of-an-inch manufacturing tolerances

by Joseph Geschelin

"Millions" and "millionths" are getting so kicked about nowadays that they no longer bear any semantic impact. While the former is being closely associated with expenditures, the latter has currently been denoting quality; quality of extreme precision. Here, the old analogy of the human hair has lost its significance completely, for, the diameter of an average strand of hair is about 0.003 in.—a frame of reference as much as 100 times greater than the allowable tolerances for certain missile components.

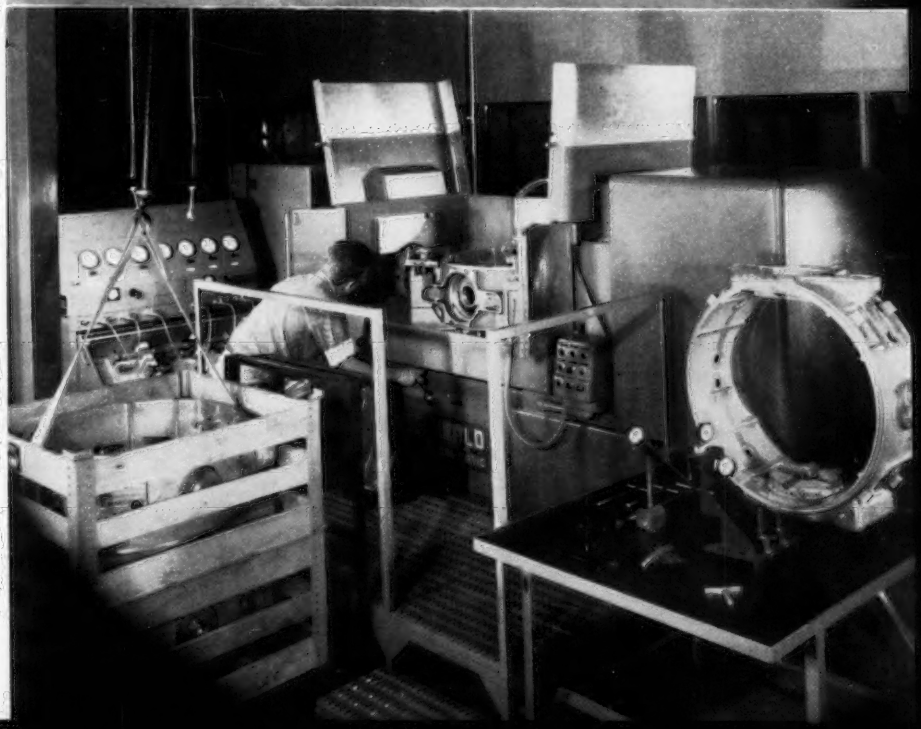
Such fine tolerances are no longer just subjects to speculation but a reality at AC Spark Plug (Division of General Motors Corp.) Wisconsin, where inertial guidance as well as ground control systems are being volume produced for the Thor, Regulus II, and Matador missiles. Volume production here is not meant to signify mass production; it is manufacture in quantities larger than hitherto attempted, for an article of this nature. This inertial guidance system called "the AChiever" was developed in a span of 18 months, and its manufacture is presently supported by some 3200 sub-contractors. It has been proven in laboratory, sled and flight tests up to an acceleration of 19 g's, and culminated in the successful launchings of the Thor last December at Cape Canaveral. As a volume production item, it is said to be 10 to 100 times more accurate than one required to put a satellite into orbit, to qualify

Precision-boring and facing of gyro platforms on Ex-Cello-O machines with independently heated spindle heads.

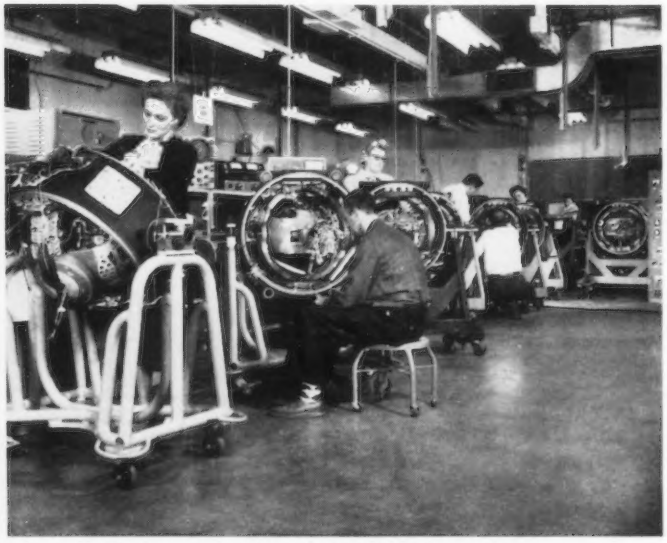


Special eight-station radial drill press drills and taps gimbals without removing and resetting. Parts roll on fixture from station to station, and are automatically positioned.

Heald Bore-Matic precision-bores gimbals within 0.0002 in. Finished part is shown at right.



Completed inertial guidance system being checked electronically in final test room.



Final assembly line of gimbal systems shows relative size and complexity of gyro unit.

Deburring of gyro components is accomplished under microscope. Special garments guard against lint contamination.

Thor's brains

continued

for the more difficult task of directing a missile to a specific target on the earth's surface.

The extent of accuracy of the gyroscopes of this system is illustrated in another way by saying that if they were used to measure the motion of a wheel instead of missile direction, they could sense movement at the rate of one revolution every 14 years.

Typical Tolerances

- Precision raw castings are machined to 0.000025 in. parallelisms.
- Hole sizes are held to 0.0002 in., and hole spacings to 0.0005 in.
- For each new set-up of Heald Bore-Matics precision-boring machines the alignment of spindles, tables, and fixtures is adjusted in two planes to a total of 0.000025 in. for squareness.
- Mounting surfaces are machined at right angles to bores within 0.000050 in.
- Squareness and alignment of gimbal ring bores, on each side, are kept within 0.0002 in. in 20 inches.
- The temperature of spindle heads on precision-boring machines is maintained within 2° F to prevent dimensional changes.
- The taper of the gyro wheel must not exceed 0.000050 in.
- The mass shift of the gyro wheel on its bearings is held to 0.000001 in.
- Federal air gages used in manufacture are accurate to 0.000001 in.
- In the assembly of gimbal rings the angular relationship between component subassemblies is held within several seconds.

Digital counters and optical alignment tools are used to test accelerometers.

- The allowable gyro drift error, upon assembly, is equivalent to no more than one revolution in 10 years.

AC has a group of 1400 engineers and electronics specialists assigned to the production of these units, in Milwaukee; and in addition to the effort spent in manufacturing, appreciable strides have also been made in product improvement. It is reported that, in certain areas, weight reductions realized through design refinements in the past two years have reached 75 per cent. Printed circuits are presently being adopted where applicable. Although the current Thor guidance system incorporates vacuum tubes, a completely transistorized system has already been developed, also for Regulus II. A considerable portion of the characteristic high standards of accuracy has been attributed to the fact that in many cases even the most accurate machine tools available are procured disassembled, and reworked to make them adequate for this type of production. A secondary machining department concerns itself with the alignment of machine tool elements within 0.000025 in.

Special Measures

To reach and maintain these stringent standards of precision, various environmental control and special manufacturing methods have been adopted. Metal cutting machinery is housed in a temperature-controlled enclosure. Spindle heads both on Heald Bore-Matic and Ex-Cell-O boring machines are kept at a controlled, elevated temperature to preclude variations in temperature and consequent dimensional changes through operation. Each machine is equipped with an adjacent Federal electronic amplifying gage for the immediate inspection of critical dimensions.

In view of the critical tolerances required throughout the system, it can be appreciated why dirt particles or burrs even in the order of two-microns (micron equals 0.00003937 in.) can not be tolerated during assembly operations. Therefore, all assembly is effected in an air-conditioned environment kept at 75° F with humidity controlled at 30 per cent.

Surgical Cleanliness Required

Personnel involved in this phase work clad in nylon hats, smocks, and shoe covers; and they gain access to their working booths through a blowdown chamber with a 30 mph air velocity. Only lintless paper and ball point pens are used for note taking. Use of nail polish or face powder is taboo.

Deburring constitutes an extremely important phase of the finishing operation, and it is accomplished meticulously with dental instruments under 30-power microscopes; sand-blasting, vapor-blasting, and metal-particle blasting are also used for this purpose. All parts, tools, and fixtures are ultrasonically cleaned before use.

• INERTIAL GUIDANCE; BASIC PRINCIPLE AND PURPOSE

Inertia is defined as the property of matter by which it will remain at rest, or in uniform motion in the same straight line or direction unless acted upon by some external force. This property is utilized through a self-contained system, to guide a missile to a point in space where it can be released from all control and fall to its target. The inertial guidance system is called "self-contained" because it sends out no signals nor receives any to make it function; hence, it is immune to jamming.

The mechanical portion of this system consists of a gyro-stabilized platform which is kept fixed in space, and serves as a plane in relation to which all movements of the missile about its roll, yaw and pitch axes are precisely measured. The platform is actually an assembly of gimbal rings which houses the gyroscopes. In the AChiever system there are six gyroscopes; three large ones to stabilize the reference platform, and three smaller gyros called accelerometers which sense the exact speed and direction of the missile throughout its trajectory. Should the missile deviate from its programmed trajectory, through externally imparted motion about its pitch, yaw, or roll axes, the accelerometers sense and feed this information into a computer. The computer instantaneously evaluates the situation and relays a compensating command to the control system involved. The range of a missile is controlled by its speed and attitude about its pitch axis, and its track is determined by movement about the yaw axis. It is also necessary to keep the missile from rolling about its longitudinal axis in order not to interchange the pitch and yaw axis during flight. This would cause reversal of control and consequent failure of the missile.

XM-77 nose cone

features 6061 aluminum-alloy, inert-arc welded structure

by **E. C. Cook**, Development Engr.
Jet Division, Thompson Products, Inc.

Fig 1: Assembled XM-77 nose structure being checked on Bullard vertical lathe for concentricity at critical joint diameters, and at extreme tip.

Annealed condition, with 20.4 per cent expansion: Parent metal is ruptured.

Annealed condition, with 23.1 per cent expansion: Parent metal is ruptured.

Solution heat-treated condition, with 25.7 per cent expansion: no rupture occurred.

Solution heat-treated and age-hardened condition, with 9.8 per cent expansion: weld and parent metal are ruptured.

Fig. 2: 6061 alloy cones after expansion tests. Cones were welded with 4043 alloy filler by automatic inert-arc, consumable-electrode process. Expansion values given are the last diametric expansion values recorded before rupture.

This long, slender structure is deceptively simple in appearance, but its design presented difficult engineering and manufacturing problems. The structure had to be as light as possible, yet withstand extreme stresses and vibration. This nose cone had to be made in three sections to provide ease of assembly for installing the warhead and other internal components.

The design and fabrication of this 12.5-in. diam nose cone, for a ballistic missile, is one example of the diversified activities of Thompson Products, Jet Division.

Working from general specifications provided by Picatinny Arsenal, N. J., the nose-cone structure was designed to withstand launching loads up to 75 g, and transportation loads up to 20 g. Overall deflection was held to a maximum of 0.250 in. and concentricity within 0.040 in. on the entire 80-in assembly. Weight limitations were set at 40 lb maximum.

Development of skin forming and welding was started as soon as design analysis had progressed far enough to establish material and thickness. Stress analysis indicated that 6061-T6 aluminum alloy could be used for the skin sections but a weld joint, if used, would have to be at least 80 per cent efficient to insure structural integrity under launching and transverse impact loads. Weld-filler material had to be as strong as the parent metal in all conditions of heat treatment.

Continued on next page

Accordingly, automatic inert-arc, consumable-electrode welding techniques were developed on sample specimens of 0.080-in. 6061-O alloy using several filler-wire materials. Tensile tests of samples indicated that welds with 4043-alloy filler were fully as strong as the parent metal in the various heat-treat conditions, even though the 4043 material ordinarily does not respond to heat treatment.

Tests were conducted to determine the expansion characteristics of the weld and parent metal. Figure 2 illustrates the results of expanding 6061-alloy sample specimens in various conditions. The cones in the solution heat-treated and annealed conditions expanded far beyond requirements of this application, without indications of weld failure.

Considerable development was necessary to produce porosity-free 4043 welds using the automatic inert-arc consumable-electrode welding process. The effect of each process variable had to be determined by correlation with x-ray and micro-inspection of weld. Micro-porosity, which cannot be detected in x-ray prints without the aid of a magnifying glass, was the most difficult to control.

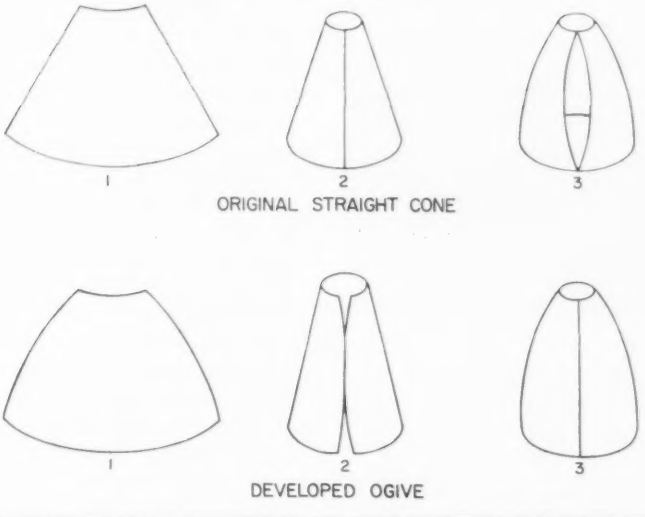
The ogive skins were developed from sheet material in the sequence shown in Figure 3. The first blank was developed, rolled, and then formed to contour in a die. The open joint was measured along its length, and equal amounts added to the blank template along the joint. Successive blanks, when formed and welded, provided a skin section which was very close to size. After solution heat-treatment, the final sizing resulted in uniform elongation along the entire welded joint.

Assembly of the fabricated skins and machined components required particular care since the prototype units were drilled without use of fixtures. Skin supports, spacers, and rings were mounted with the skin on the indexing plate of a De Vlieg jigmill. All parts were aligned for squareness and concentricity, then drilled for assembly.

Rivets were used to join all skins and internal supports, utilizing a standard aircraft-type squeeze riveter with a special throat section. Standard AN rivets of type "D" (2017) were used on all sections except the last. Here the high shear loads required the use of type "DD" (2024) rivets.

Further development of the nose structure will incorporate weight saving features through the use of plastics and chem-milling. Spin-forming is also under consideration, to preclude welded joints.

FIG. 3: DEVELOPMENT OF CONICAL SECTIONS.

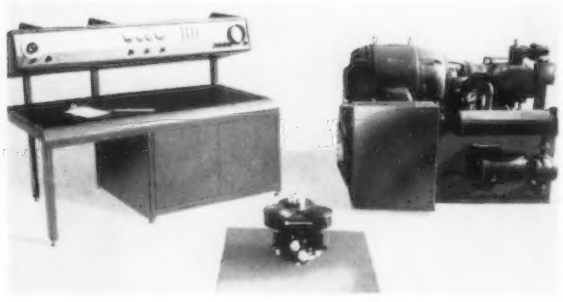


techniques simulate forces of nature on ground, to enhance aircraft and missile reliability

environmental testing

by John P. Kushnerick

Transonic wind tunnel test section entrance illustrates immenseness of some environmental testing facilities. Men are dwarfed in this downstream view through the sidewalls of the flexible nozzle of Arnold Engineering Development Center's 40 ft long transonic propulsion wind tunnel. Ceiling and floor are fixed, flexible sidewalls are adjusted by motor-driven jacks to create test velocities up to 1,100 mph.

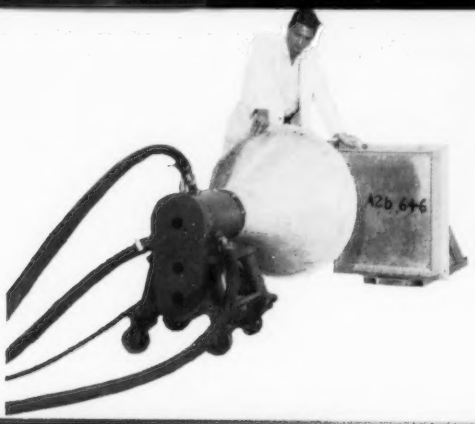


Three basic units comprising the Wyle Hydrashaker vibration excitation system for applying high acceleration forces to missile components are: the control console, which integrates all electronic equipment and controls, the power supply unit for conversion of electrical power to hydraulic power, and in the foreground, resting on a block, the small 75-lb exciter unit whose 16-lb moving-assembly is a key factor in the system's high acceleration capabilities.

Man's battle with the elements in his endeavor to fly higher and faster has resulted in the paradox of requiring vehicles of increasing complexity with simultaneous demands for increased reliability, all while operating in environmental extremes that strain to the limit man's knowledge of materials.

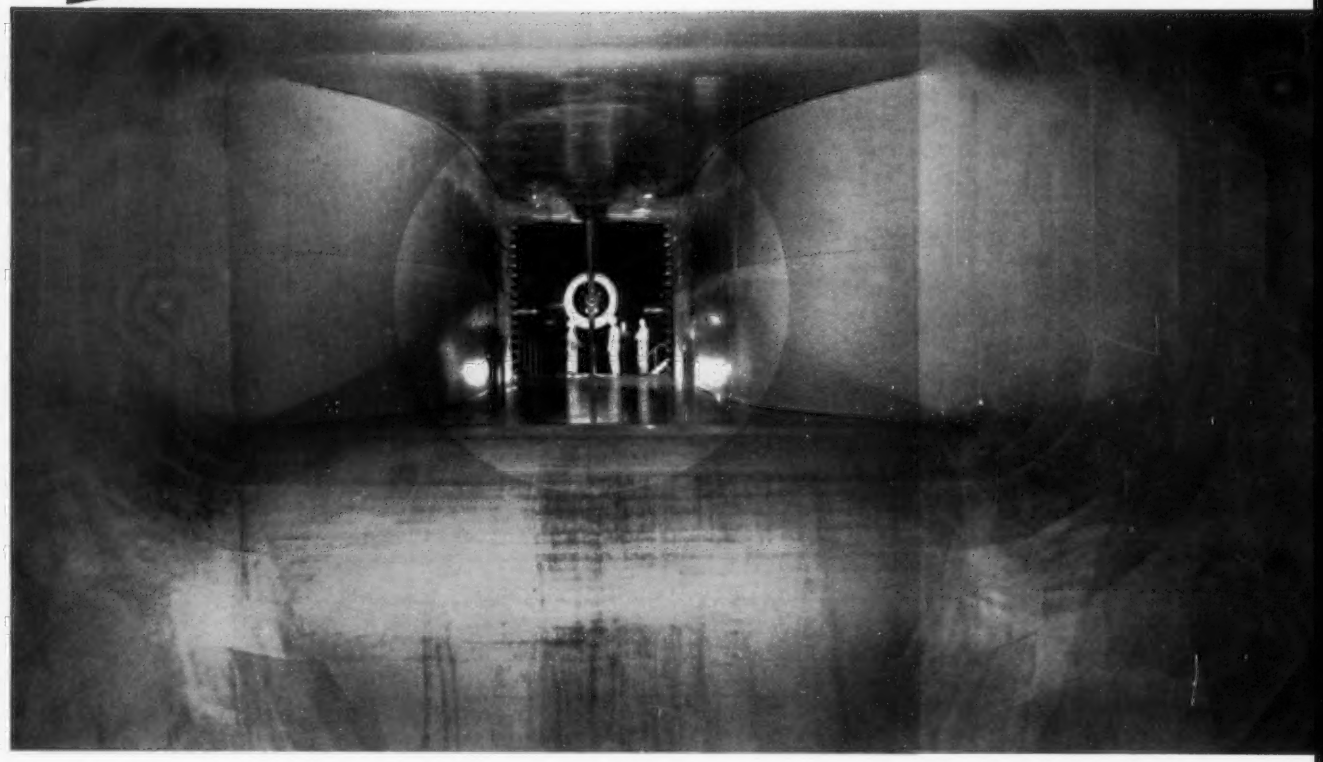
The science of environmental testing has grown out of an inability to accurately design against, and predict the consequences of, the forces of nature from the information at hand. It is the result of the school of thought that there is only one course to follow in being reasonably sure an aircraft or missile will perform reliably in a given environment, that course is to test each component in the environment it is expected to encounter and resist.

This science is now an integral part of aircraft and missile manufacturing as well as



One of two test cells and the sound-generating horns at Boeing Airplane Co. Sound with a pure sine-wave form is generated by compressed air whose flow is interrupted by a motor-driven chopper valve and then amplified by an exponential horn. The generator will convert 4,000 cubic feet of air per min from two 400-hp air compressors into about 190 decibels of sound for test purposes.

During a test, the specimen is placed directly in front of the exponential horn. The panel undergoing tests vibrates back and forth at its sympathetic, or resonant frequency. The amplitude of vibration is the destructive force which interests the environmental test engineer.



it is a part of basic research; in that, information gathered in research about materials must be applied and extended to the specific configurations and applications in manufacturing. There is a growing closeness of research, design, and production in aircraft and missile manufacturing. The time lag customary in the past, between the research and the production phases of an item, is being progressively compressed. This contraction has occurred to such an extent that today, production problems are finding their way into the researchers realm, and the researchers laboratory findings are being tried and extended in manufacturing plants by design and production engineers before they are completely crystallized. Problems are encountered that have been unforeseen, yet demand an immediate solution to insure vehicle reliability in the relentless forward movement.

Environments—Singly and in Combination

The cost impact of environmental testing on producing commercial aircraft, fighters, bombers, and missiles will probably never be accurately tabulated. Elaborate simulating equipment has been built in virtually every major research and manufacturing facility in this country. Environments must be simulated singly as well as in combination. Some of simulated environments are for:

- Aerodynamic heating
- High velocity shock
- Dust and precipitation erosion
- Sonic and ultrasonic vibration
- High acceleration
- Solar radiation
- Zero gravity

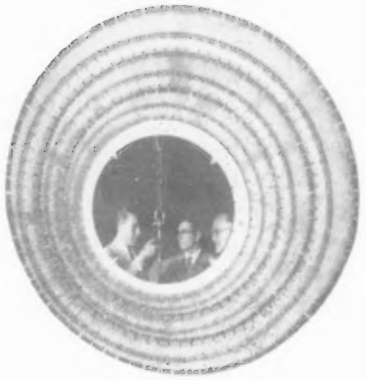
Continued on next page

continued

Areas of Impasse

There has been objection in some areas to the use of the term "barrier" when speaking of the temporary impasses imposed by nature at Mach 1, and subsequently at higher Mach where aerodynamic heating has become severe.

Regardless of the terminology applied, it cannot be denied that nature has imposed some formidable obstacles to man's progress in a new domain. In the quest for metals to withstand high temperatures for example, ductility has always been a primary design requirement, yet the limiting factor of nearly all high melting alloys is the lack of ductility.



Cone-shaped test furnace designed to simulate the heat and stresses encountered by the Redstone missile on reentry into earth's atmosphere at supersonic speed. The test device contains a battery of more than 1,000 quartz infrared lamps.

Conditions Encountered

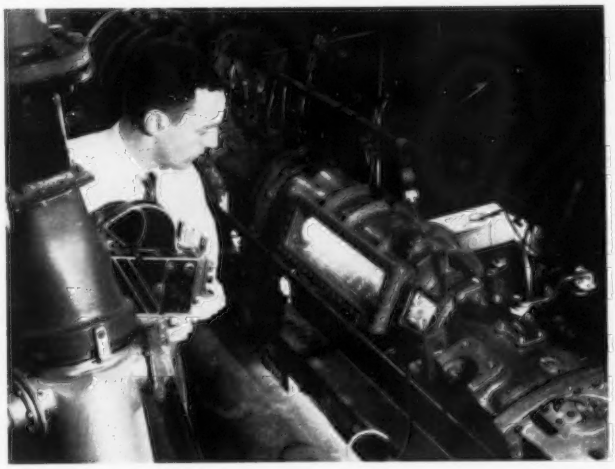
The high shock and acceleration forces encountered in transporting and launching a missile might logically lead one to think that its components should be heavy, massive structures. Yet the opposite is the case, missiles must be guided by instruments of extreme delicacy and light weight.

The shocks encountered in transporting a missile are generally as severe as those encountered in launching. On the basis of recorded data the maximum shock amplitude encountered has been 20g. Using a calculated response amplification of 1.75 based on sinusoidal pulse input, the peak value is calculated at 35g. Using a safety factor slightly greater than two gives 75g for a design and test requirement. Specifications have been established which state that missile shock testing shall induce a linear increase from 10 to 75g over a frequency band of 10 to 100 cps, with a constant 75g from 100 to 1000 cps. A 100g shock in six mutually perpendicular directions is recommended to cover a multiplicity of shock applications.

The intensities and durations of g in aircraft vary from point to point, but peaks of 17g for 13 milliseconds have been recorded in high performance aircraft fuselages, and 38g for 34 milliseconds in corresponding wings. The need for environmental testing is readily apparent in these few cases if reliability is to be attained in the final vehicle.

Wyle Manufacturing Corp. has produced a "Hydrashaker" which uses hydraulic power to create combinations of forces, accelerations, and frequencies for testing aircraft and missile components in the shock environments described.

The consequences of ultrasonic noise vibrations are often disastrous to structural metals.



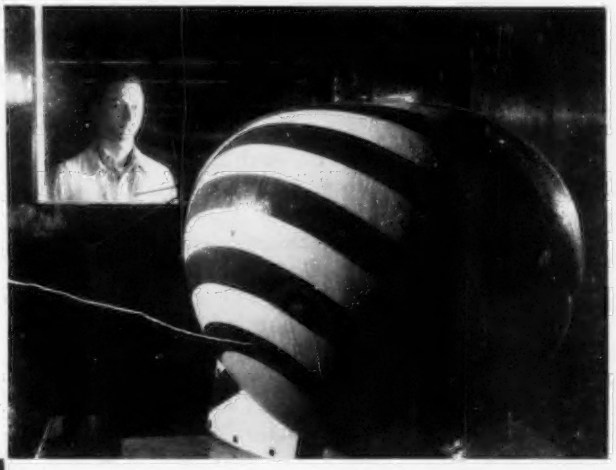
Decreased resistance to fatigue failure is a consequence of these vibrations. The unfortunate crashes of the Comet airliners have been traced to a progressive fatigue condition which was the result of such unforeseen environmental conditions. Subsequent to these mishaps, serious environmental testing to study fatigue resistance was initiated at several research and manufacturing organizations. Latest production models of the Martin P6M show modifications (engines canted outboard) which are the result of these tests and environmental data compiled in initial flight tests. In the latter case, a combination of heat and ultrasonic vibration were feared to cause lowering of resistance to fatigue, of fuselage skin and longerons, in the area of the turbine exhaust (particularly true on "Y" models which are equipped with afterburner).

Boeing Airplane Co. has recently completed a $350,000 noise generating laboratory to simulate high frequency noise environments for test-

Supersonic aircraft model is prepared for testing in the 10 x 10 ft supersonic wind tunnel at the NACA Lewis Laboratory. This facility permits testing of aircraft engines and their components at speeds of 1500 to 2500 mph at simulated altitudes up to 30 miles.

Compressed air blowpipe hurls hailstones the size of golf balls against wing sections of the Convair 880 jetliner to test structure's durability under severe weather conditions. This is an instance of environmental testing enhancing reliability while the aircraft is still in initial stages of production. 880 will not be rolled out until about October 1958.

Engineer adjusts a camera that will record the effects of various high energy fuels on aircraft gas turbine components in evaluation studies at NACA Lewis Flight Propulsion Laboratory. Some of the recently publicized high energy fuels are known to have deleterious effects on in use materials. Only through environmental testing can these effects be fully evaluated.



Salt spray and humidity-temperature conditions are created to environmentally test the radome of the Navy A3D's automatic armament system. The equipment is placed in the room temperature chamber that has a relative humidity of 95 percent. The temperature is then raised to 185° F within two hours, remains there for six hours and then is returned to normal for 16 hr before the cycle is rerun.

ing fatigue on panels and actual aircraft components. Sonic generating equipment will produce 190 decibles of pure sine-wave sound.

Jet engines installed in sections of the aircraft are environmentally "test flown" inside a closed circuit wind tunnel at the Arnold Engineering Development Center. Matching an engine with a specific airplane or missile involves special design problems that cannot be resolved with any finality on "the board." Airflow into the engine is critical and engine power data established in open air tests are not reliable. This was proven with some unpleasant consequences in the development of the initial McDonnell F3H. The efficiency of engine inlets, which must be large enough to provide the engine with adequate air, yet be shaped and sized to reduce drag, must be determined in actual mockup installation for various altitudes, speeds and flight attitudes.

A fiberglass radome that houses the automatic armament system for a Navy all-weather interceptor is examined at —40° F. Airborne gun-aiming systems are actually put into operation at temperatures as low as —75° F and simulated altitudes of 90,000 feet.

component testing—quality control

sub-assembly checks assure final product reliability

by E. E. Gaudet and A. J. Wesolowski, design engineers, Aircraft Generator Engineering, General Electric Co.

Rejection on final test of a highly engineered and complex product due to failure or malfunction of a component usually results in unnecessarily high rework or scrap costs. This problem was overcome in the manufacture of aircraft generators by General Electric's Direct Current Motor and Generator Department by instituting a system checks to assure necessary high quality levels before final assembly.

Aircraft generators are not tooled for a large production rate. Considerably handwork is involved, made necessary by the need for a wide range of design and manufacturing variations. Effective quality control on each manufacturing operation assures uniformity of parts and components and an end product that can be held within extremely narrow performance limits.

Illustrations show the generator schematically broken down into its major components and an exploded view of the product. There are two separate generators within the unit—the main AC generator and its exciter.

60 KVA Self-Exciter AC Generator Characteristics

Model—2CM214B1B
Rating—60 kva, .75 pf, 3 phase, 380/420 cyc, 5700/6000 rpm 120/208 V.
Weight—120 lb
Cooling—Self ventilated
Ambient air—160°F
Efficiency—85% at 6000 rpm, 60 kva, .75 pf
Insulation—class B
Overloads—90 kva, 5 min;
120 kva, 5 sec
Brush life 1000 hr
Bearing life—1000 hr
Diameter—11 in.
Length—19 in.
Excitation—integral exciter

Stator

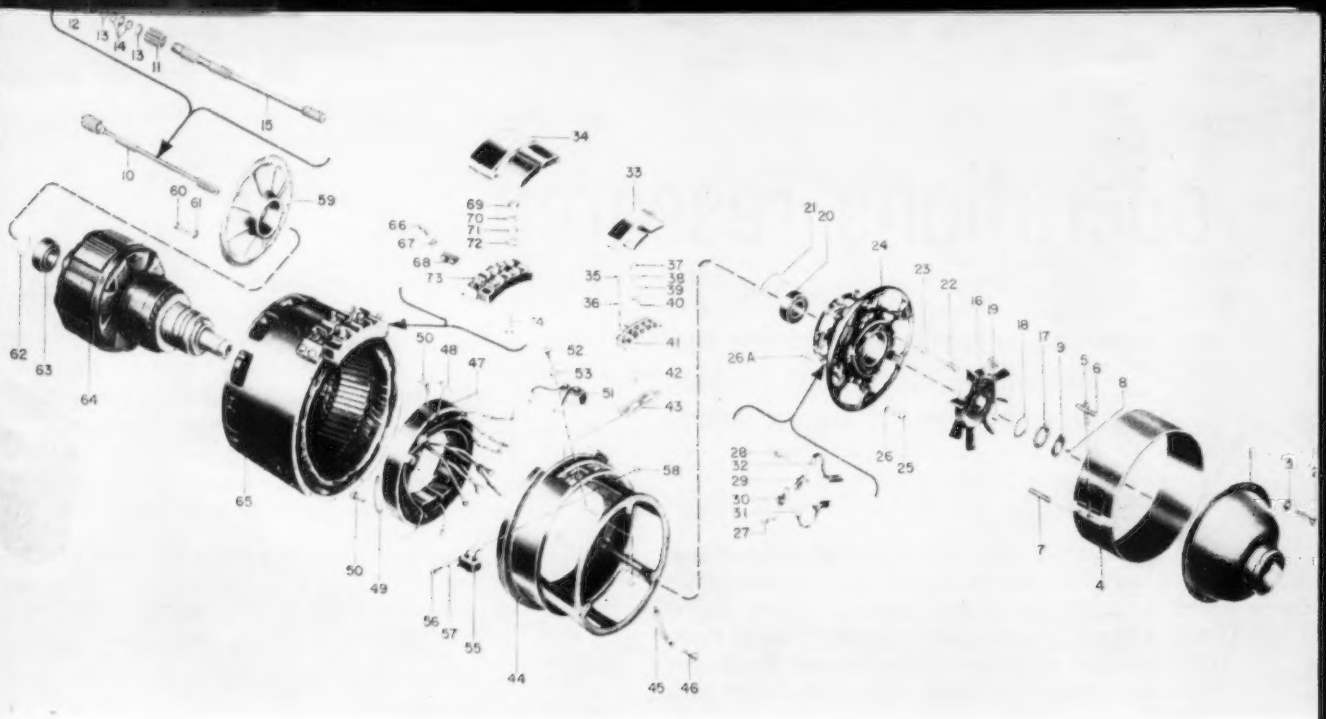
The punchings for the AC stator, which is the main component are made from coil stock (cold rolled and bright finish). These cannot be used as such but must be annealed and oxidized to produce the desired magnetic properties. It is imperative to control quite closely the annealing temperature and time, as well as the amount of oxide deposited on each punching. To check the magnetic properties of the punchings, a device called a "single turn tester" is used. Here a punching stack is excited at the proper frequency and magnetic characteristics in the iron but serves also as a check on the basic material quality, and furnace operation. These punchings are then fabricated into a core; the core is again spot checked by use of the single turn tester; and again faulty cores are rejected and manufacturing processes are reviewed.

Stator Coils

The next step is the insertion of the coils in the stator coils. Besides checking insulation resistance by hi-potential testing, and the wire resistance to assure proper electrical joints, the completed stator is subjected to a surge test which impresses a step-function voltage of high potential to the windings. This checks phase-to-phase and turn-to-turn insulation resistance as well as the symmetry of windings. Also, a final excitation test is performed by inserting a slotless laminated core in the stator bore and applying power to the windings, noting the input and comparing this against the standard.

Exciter Field

The exciter field, part 47 on the exploded view, consists of an iron ring, (which carries flux), main field poles, interpoles, and windings. Because of the simplicity of construction and ease



Nomenclature

1. Air inlet cover
2. Screw
3. Washer
4. Brush inspection cover
5. Screw
6. Pin
7. Pin
8. Screw
9. Retaining washer
10. Inner shaft asm.
11. Coupling
12. Spacer
13. Ring
14. Retaining ring
15. Inner shaft
16. Fan
17. Nut
18. Lock washer
19. Key
20. Ball bearing
21. Clamp
22. Screw
23. Washer
24. Brush rigging asm.
25. Screw
26. Washer
27. Screw
28. Screw
29. Spring guide
30. Spring
31. Alternator brush
32. Exciter brush
33. Exciter terminal block cover
34. Alternator terminal block cover
35. Screw
36. Clip
37. Nut
38. Washer
39. Check nut
40. Lockwasher
41. Terminal block
42. Terminal
43. Exciter terminal block insulation
44. End shield
45. Pressure plate
46. Bolt
47. Exciter field wound
48. Bolt
49. Pressure plate
50. Bolt
51. Capacitor
52. Screw
53. Washer
54. Nut
55. Lead and capacitor asm.
56. Screw
57. Washer
58. Nut
59. Bearing support
60. Screw
61. Washer
62. Retaining ring
63. Ball bearing
64. Armature and rotor asm.
65. Stator wound asm.
66. Bolt
67. Lock washer
68. Clip
69. Nut
70. Washer
71. Check nut
72. Washer
73. Alternator terminal block
74. Alternator stud

of disassembly, this is tested as a unit. For this check, a standard armature is used, rotated at a given speed, thus acting as a self excited DC generator. The excitation measurements serve as a check of quality. The exciter frame is a lightweight aluminum alloy casting which undergoes standard checks for porosity, machining dimensions and squareness of mounting faces.

Rotor

The next major item is the AC rotor, which furnishes the excitation power to the generator and carries the main winding as well as the amortisseur windings. Only a few turns of heavy wire are used here, and it is important that there be no shorted turns or turns missing. The punching and cores are tested in the same manner as in the stator. The completed rotor is subjected to a flux test to determine shorts and deficiencies. Because of the large distance between poles, the magnetamotive force can be measured accurately and even one turn shorted or missing can be readily detected. This test is performed immediately after winding insertion and also on the completed rotor. This is the most valuable functional test. Furthermore, at this stage, repairs can be made without too much trouble.

The exciter armature is treated in much the same manner as the AC rotor; the shaft is checked for machining tolerances with gauges, and for surface cracks by Magnafluxing.

Since the institution of the foregoing procedure, a substantial decrease in rejected parts and a much more uniform product have resulted.

operations research

can serve as a scientific tool helping management develop products to meet changing needs

by C. Locurto, test planning engr., General Electric Co.

Recently, after five years of development work, a certain aircraft company producing military aircraft, had a multi-million dollar prime contract cancelled, much to the surprise of management and employees. The reason given was that the military planning and procurement policies of five years ago which influenced the development of the aircraft were no longer realistic in the light of present day logistics. However, the aircraft was being considered for procurement in limited quantities for a mission which was vaguely similar to the original military requirement. Soul-searching study on the part of the manufacturer revealed that the aircraft was just too heavy; in addition, the extensive equipment required to support it in the field killed all foreseeable chances of using it.

How does such a complex product as an aircraft, almost overnight, become relegated to limbo? Does obsolescence occur suddenly, or is it a gradual process, predictable to a considerable extent?

An analysis in retrospect may reveal a number of pitfalls not uncommon to both commercial and defense production.

In this case the manufacturer felt secure in designing to meet original requirements; requirements dictated by conditions which can hardly remain static for very long.

Secondly, the enthusiasm of a military service component for the aircraft was interpreted somewhat too broadly, and no immediate concern was manifested towards radical changes to extend the apparent market.

Lastly, it suddenly became evident that the old axiom that "an aircraft usually does end-up heavier than first anticipated" has outlived its usefulness.

Management felt that whenever the military services needed a new aircraft the company would submit proposals and make bids as usual, relying on past experience and reputation. This is a most natural philosophy, but unfortunately it tends to lead thinking more along preconceived paths than along new avenues seen in the light of changing needs.

The professional operations researcher may analyze the foregoing situation somewhat as follows:

Market Intelligence

The fact that a military service or its component is enthusiastic about a system does not fix the market location. There is sometimes a variance of opinion between different military service echelons concerning needs. The propriety of the location must be examined, otherwise one will find himself dealing with the wrong customer.

Criteria for pinpointing the market is developed by extrapolation into future roles and missions. To anticipate the military level and extent of the market, service attitudes and prejudices must be studied. Likewise, the market position, reputation, and capabilities of potential competitors must also be considered.

Engineering Systems Analysis

STATEMENT OF PROBLEM: This step requires consideration of the probable economics and geopolitics and their possible variations during the future period from design to production, as well as probable technological development, weapons, and equipment in the projected period. Obviously, these factors are not amenable to accurate determination, particularly where they involve enemy objectives and intentions. In such cases, it is often necessary to postulate a range of possible values of these factors and to carry them through the analysis to learn their effect on the results.

DERIVATION OF THE MEASURE OF EFFECTIVENESS: This is the most important and difficult part of the analysis. A mathematical model must be developed for this step stating the fundamental transaction taking place between opposing systems, with terms expressing the important variables in the airborne weapons systems. The purpose of the measure is to provide a yardstick

by which one may determine the individual efficiencies and reliabilities of a whole series or spectrum of candidates for accomplishing the specified military mission.

Fundamentally, the measure will contain terms relating the capabilities of the system, and terms relating the cost of accomplishing the mission in this manner.

STUDY OF OPPOSING WEAPONS, EQUIPMENT AND TACTICS: Where applicable there should also be a study of the developmental programs and a forecast of the airborne weapons and equipment that could be made available operationally to the armed forces during the projected period. This investigation may reveal apparent functional requirements for weapons not yet conceived or planned, but considered technically feasible.

SYNTHESIS OF POSSIBLE SOLUTIONS: To this end, a series of complete aircraft configurations, or weapons systems, with suitable variations in performance parameters are chosen, and parametric analysis is carried out in which performance and characteristics for a spectrum of aircraft are computed. This will involve a complete weapons system, where aircraft, weapons, equipment, crew and vehicles are considered, and represent a range of functional and performance capabilities of both the military load and the aircraft.

EVALUATION, ANALYSIS AND CONCLUSIONS: Using the strategies and tactics previously determined, the various weapons systems are evaluated for the prescribed mission in opposition to the enemy's forces by application of the measure of effectiveness. The value of the measure is optimized for our side, and conclusions are reached as to the characteristics of the best systems. If answers are sensitive to certain indeterminate factors, such as those under control of the enemy, they may be expressed in terms of a range of these factors. Alternate or compromise solutions are sometimes indicated. In such cases the penalties for compromise in non-optimal selections are specified.

Operations Research at Project Level

A time-honored cartoon, that has been on walls of aeronautical engineering departments for many years, depicts the airplane as seen through the eyes of the different specialist groups that contribute to the conception of an aircraft. It suggests humorously that these various specialists have a somewhat distorted view of the importance of their particular province in airplane design. The wing group sees the airplane as all wing; the weight group wants it made of balsa wood and microfilm; the production engineer wants to turn it out like Sears Roebuck and Co. fences; the powerplant group sees a flying engine with certain necessary, but inconsequential, appendages, etc. Most of these engineers will probably admit that miraculously enough, after suitable bludgeoning by the preliminary design engineer, the project engineer, and the chief engineer, a flyable machine results.

In the case of the manufacturer of the cancelled aircraft, the fact that the aircraft was overweight suggests a weakness of scientific coordination between project groups and sub-groups. Coordination can be achieved through the medium of sub-system specifications, a model or breadboard arrangement to interrelate the sub-systems, etc. In short, scientific methods can be made available to the project executive to aid his planning and scheduling functions.

From the foregoing discussion, the author has endeavored to give a brief insight into the domain of Operations Research. Some good definitions for this important function follow.

The Operations Research, or Operations Analysis group, sees the airplane (a weapons system), the logistics that support it, and the operations it performs as a total system or entity.

Operations Research applies scientific method, tools and techniques to improve the planner's basis for decision, and the probability that a newly conceived airborne system will reach maturity and live out an efficient combat life.

The first responsibility of Operations Research is to interpret and to place a problem in its proper perspective by considering all external factors that can affect the problem.

Perhaps the most singularly important definition of Operations Research is that it applies scientific method to the solution of operational problems which are of importance to the executive. This may involve highly placed executives, and it follows that the Operations Research group should be staffed with persons of the highest possible caliber. They should have a diversity of specialized educational background and practical experience to bring true perspective and a large storehouse of scientific discipline to their work. Obviously, this group should be so placed in the table of organization that they are afforded a wide scope of action.

It should be stressed that Operations Research personnel do not make decisions. They render available solutions understandable to the executive. They ascertain the validity of research results, and they assist the executive in the efficient application of the results.

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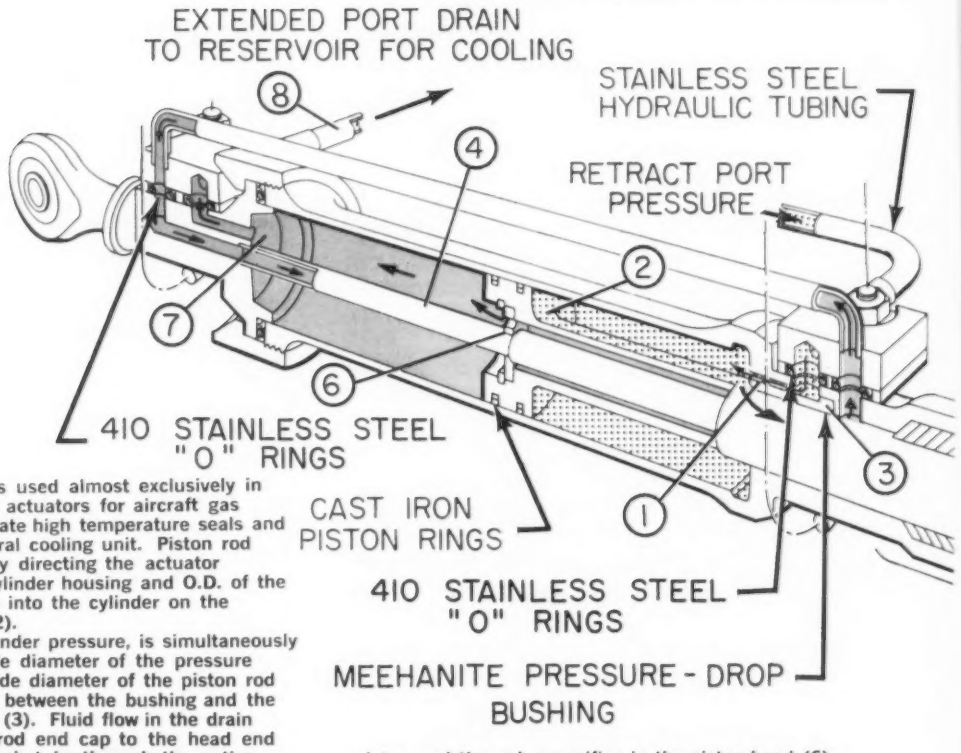
high-temperature hydraulic actuators

in gas-turbine exhaust and afterburner regions, incorporate cooling systems to endure rigors of environment



Series 410 stainless steel is used almost exclusively in high temperature hydraulic actuators for aircraft gas turbine use. Lack of adequate high temperature seals and fluids necessitates an integral cooling unit. Piston rod flushing is accomplished by directing the actuator retract fluid between the cylinder housing and O.D. of the pressure drop bushings (1) into the cylinder on the retract side of the piston (2).
A controlled flow of fluid, under pressure, is simultaneously provided between the inside diameter of the pressure drop bushing and the outside diameter of the piston rod into the drain tube located between the bushing and the low pressure chevron seals (3). Fluid flow in the drain tube is directed from the rod end cap to the head end cap and into the center flush tube through the entire length of the piston rod (4). At the end of the flush tube, the circulating fluid flows through escape holes into passages between the wall of the piston rod and the O.D. of the flush tube (5) along the passages toward the piston and through an orifice in the piston head (6) into the drain area on the actuator extend side of the cylinder (7). Drain fluid is directed to the reservoir for cooling. (8) Actuator extend operation reserves the flow of fluid through the same system.

Without variable inlet and exhaust nozzles, a gas turbine powered plane could not fly much faster than Mach 1.4 and takeoff, under certain load conditions and configurations, would be marginal. The mechanisms controlling the geometry of the airflow through inlet and exhaust ports must be powered by highly reliable actuators, capable of operating in the environments produced by combustion chambers and afterburners.

Manufacturing these actuators poses many challenging engineering problems. They must be as small and lightweight as possible, yet provide positive, precise control. Operating ambient temperatures may average 1000°F. These temperatures are the result of high Mach aerodynamic heat, radiated heat from the engine, and conducted heat at the mounting points.

Aeroproducts is one of the manufacturers of high temperature actuators for aircraft and missile applications who have some degree of success in producing units capable of operating at ambient temperatures of 1000°F.

Hydraulics

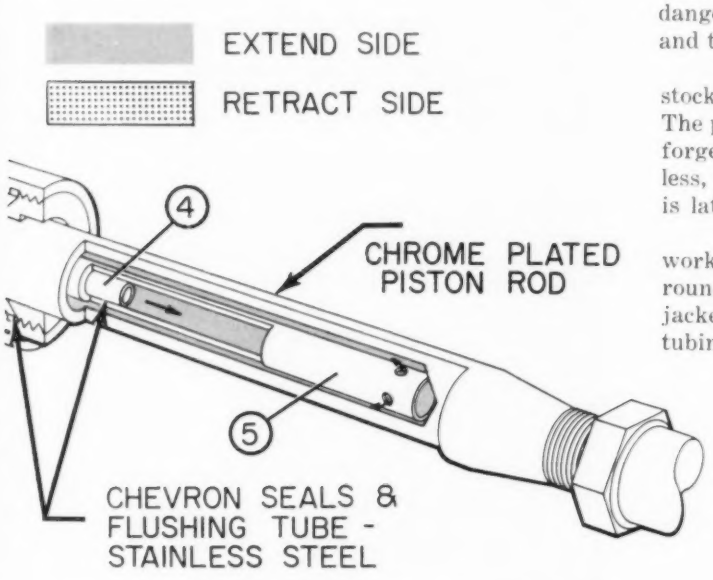
Airframe and engine manufacturers would have preferred pneumatic operation for actuators, but hydraulics more closely met the requirements of great force in a small package. They imposed several challenging problems however, the primary one being to find a stable high temperature fluid.

With the temperature of the incoming rod at about 1000°F, ordinary hydraulic fluids would vaporize and break down. Synthetic fluids studied presented a corrosion problem. The logical design approach seemed to make the system self-cooling. Thus, No. 78 engine oil was shown to be satisfactory as a hydraulic fluid.

Pressures required are between 1500 and 3000 psi. System burst pressure is 12000 psi.

Cooling

Constant circulation of oil maintains a uniform system temperature in the actuators that resulted. Oil flushing of the piston rod, through its hollow shaft, provides flow to critical seal areas and dissipates the intense heat of the incoming rod. Constant circulation is maintained by a pump. In addition, in and out movement of the rod assists the circulation. A heat exchanger in the oil reservoir cools the oil.



Lubrication and Leakage

To prevent the rod from seizing at high temperatures, constant lubrication is provided. This is done by a controlled flow of fluid under pressure between the pressure drop bushing on the rod end of the cylinder housing, and the piston rod. This provides a film of oil on the rod whether in motion or stationary.

Leakage is prevented by self-energizing metal O-rings in static application; piston rings and the pressure drop bushing act as a high pressure seal on the rod end of the cylinder housing. A low pressure seal on the rod end of the housing is provided by metal chevron seals.

Materials

Choice of materials is an important factor in designing these high temperature actuators. All high temperature metals were investigated. Unfortunately, at temperatures over 800°F titanium became brittle and was unsatisfactory, so this light metal could not be used. The material decided on was 410 stainless, and it is used almost exclusively. Even the O-rings and chevron seals are stainless steel. One exception is the piston rings, which are cast iron, split type; another is the close-fit bushings made of Meehanite. To protect against galling, the piston rod is chrome plated. The centered flushing tube and the hydraulic tubing are of seamless, stainless steel.

Construction

In the hydraulic system, all connections are welded for added reliability. This precludes the danger of forgetting to tighten bolts, and lugs, and the danger of connections working loose.

Stainless steel castings, forgings and bar stock are used for the major parts of the units. The piston rod is forged, and the cylinder is either forged or cast. The cylinder housing is of seamless, stainless tubing, and the piston end bushing is lathed out of bar stock.

Flexible tubing is used to connect actuators working in synchronization. This tubing is surrounded by a special jacket assembly, and the jacket is filled with insulation to protect the thin tubing from the severe high temperatures.

Actuators are custom-built to meet specific problems of aircraft and engine design. They have been made in sizes as small as 1 in. diam, and as large as 4½ in. They have strokes from 2½ in. to 28 in.

Heat Problems

In stagnant air, the actuators work satisfactorily at temperatures from 800 to 1000°F. The major problem is in handling incoming air that enters the vicinity of the engine at high

high-temperature hydraulic actuators

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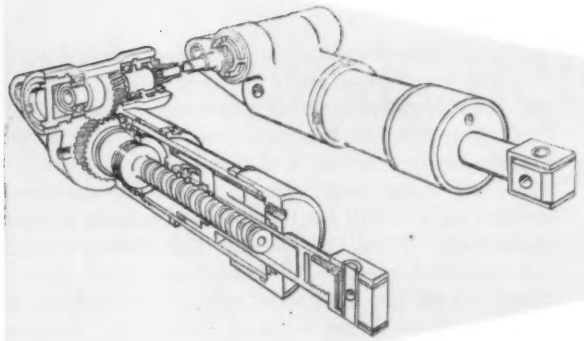


Synchronization in parallel or series is obtained by gearing the jack screws of all actuators in the synchronous chain together through shafting. The extend port hydraulic tubing may be utilized as a housing for flexible shafting.

velocity, causing differences of temperatures. The paths of these airstreams is a serious consideration in mounting the actuators on the engine.

Since stainless steel is used throughout, there is little problem with warping. The actuator has relatively small mass, and any rise in temperature is at a nearly uniform rate, so there is very little binding. The close-fit bushings of Meehanite are pressed into the stainless steel cylinder housing, and take its expansion.

As mentioned, the thin, flexible tubing connecting the actuators is protected against radiated heat by insulated jacketing.

At the point of direct mounting, the rod end picks up intense heat by conduction from the engine. This heat is dissipated by the internal oil circulation in the piston rod section.

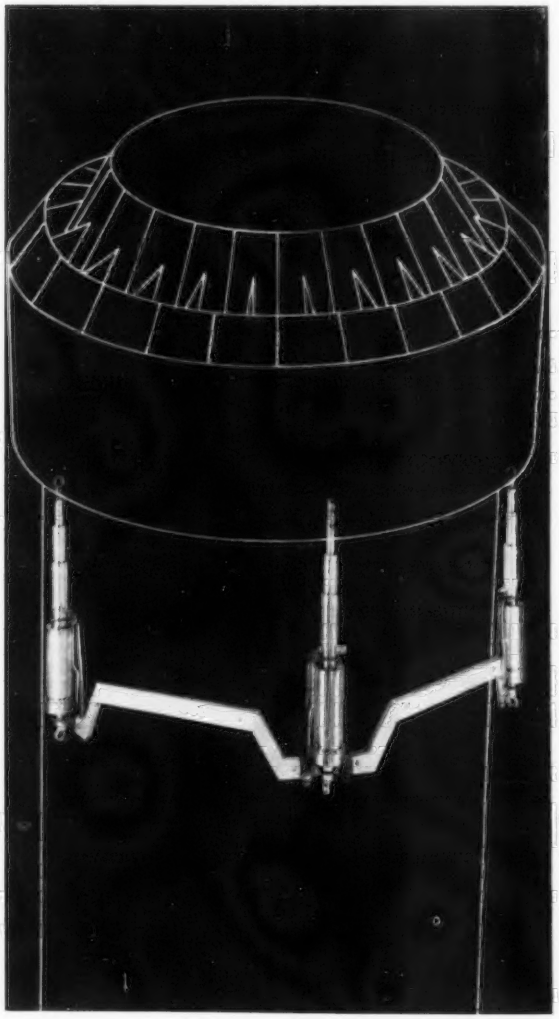
Freezing is prevented by the constant circulation of fluid under pressure.

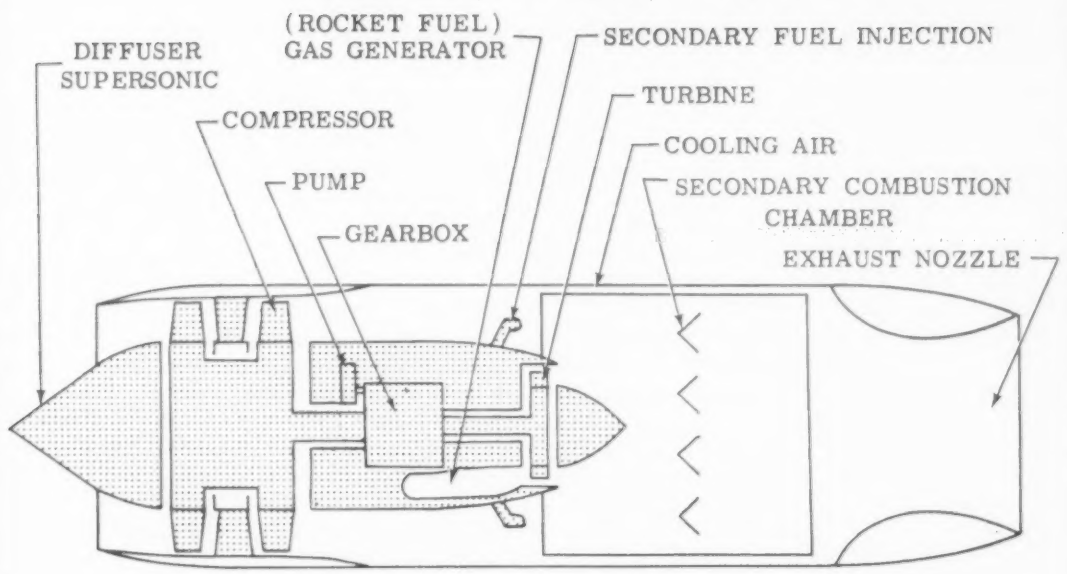
Applications

High temperature hydraulic actuators are used on engine exhaust nozzles, afterburners, thrust reversers and converging-diverging nozzles. Synchronized and brake type units are also used on rocket engines. For instance, in controlling the gimballing mechanism.

For reliability, a synchronized system uses two hydraulic pumps, either of which is capable of supporting the load.

Actuators are coupled in parallel or series around exhaust shrouds of afterburners on gas turbine engines.





comparison with molybdenum shows areas of promise

niobium for gas turbines

by **W. S. Hazelton**, Aviation Gas Turbine Div., Westinghouse Electric Corp.

Trying to keep pace with the technology of new materials on the aircraft propulsion scene has been a staggering task even to the materials engineers working with them.

One of the newest entries in the growing list of materials is niobium. Why should another be added to the already staggering list?

To answer, requires an understanding of the tremendous strides made in aircraft performance over the last few years.

Since the amount of energy released for propulsion in a turbojet depends upon the increased temperature caused by combustion, the temperature rise through the combustion chamber must be kept high. As flight speed increases from Mach 1 to Mach 4, the turbine temperatures will rise about 1000°F. Considering the enormous effort expended in developing alloys for Mach 1 operation, the magnitude of the high speed problem becomes obvious.

New Engines—New Materials

There is a type of aviation gas turbine appearing on the scene that requires much higher temperatures for efficient operation than the familiar turbojet; this powerplant is the turborocket. In this powerplant a decomposable fuel is used, energy from the decomposition of the fuel is extracted by the turbine to run the compressor. The subsequent combustion of the fuel furnishes the energy for propulsion through an exhaust nozzle. The decomposition temperature depends upon the particular fuel used, but is considerably above temperatures encountered in turbojets in current production. Materials in use today are designed for temperatures of about

2000°F, this is entirely inadequate for the power plants envisioned.

The problem of developing and selecting high temperature materials for aviation gas turbines is more difficult in some respects than that facing designers for other propulsion equipment, such as one-shot rockets. In general, aviation gas turbines are used for manned aircraft, where absolute long-time dependability is mandatory. The complexity of the rotating parts and the design problems require that the materials have ductility and toughness. Although these requirements can be lowered by ingenious design, in some cases, little use can be made of ceramics, cermets and other materials so useful in many other types of high temperature equipment. Therefore, metals and alloys must be developed with the necessary high temperature properties.

Metals with very high melting points are shown in the following table:

Metal	Melting Point °F
Tungsten	6170
Rhenium	5700
Tantalium	5362
Molybdenum	4750
Niobium	4475

Tungsten, tantalum and molybdenum have all been used for high temperature parts. Tantalum, tungsten and rhenium are all much heavier than niobium and molybdenum, which puts them at a distinct disadvantage from the important aspect of strength-weight ratio. Although these elements are necessary for temperatures near and above the melting point of niobium and molydenum, the much lower densities of the latter elements make them most attractive for aircraft and missile turbine structural applications in the next few years.

There are several general categories considered when any new material is evaluated for high temperature service. These can be listed as follows:

- Strength and ductility
- Oxidation resistance
- Ease of fabrication
- Cost and supply.

A comparison of niobium with molybdenum, a metal long studied for turbine use, in each of these categories should give a resonable estimate of its potential in aviation gas turbine application.

Strength and Ductility

Little is actually known about the strengths ultimately attainable in either molybdenum or niobium base alloys, but available data can be used to good advantage. The theoretical probabilities will be discussed later.

Figure 1 shows some typical 100-hour rupture strengths of alloys tested. Possibly because molybdenum alloys have been under development longer, the better molybdenum alloys show a distinct superiority in rupture properties. However, the niobium alloys show a marked advantage over one of the better conventional alloys, Inco 713C.

There are some other properties, not usually considered as strength properties which are very important in design. Figure 2 shows the moduli of elasticity for niobium and molybdenum with respect to temperature. Molybdenum is far superior. Although this low moduls is a serious disadvantage of niobium, alloys of aluminum and magnesium have been used for important structural parts, even though they too have very low moduli. There are some compensating advantages to this low modulus.

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Fig. 1. 100-Hour Rupture Strength of Several Alloys

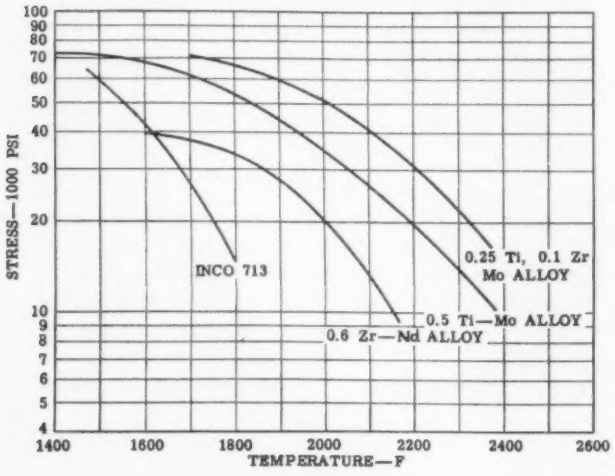


Fig. 2. Modulus of Elasticity of Niobium and Molybdenum

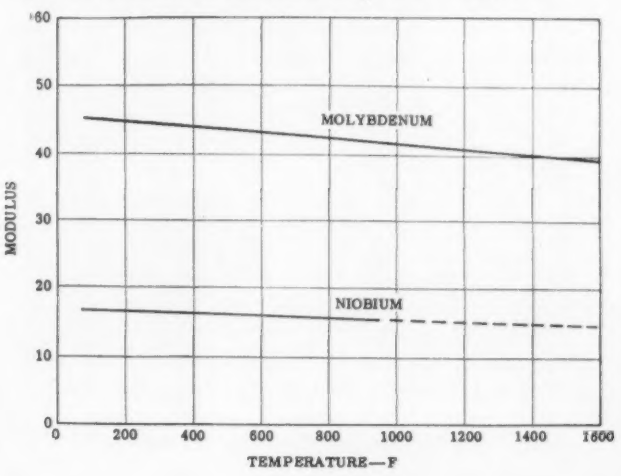
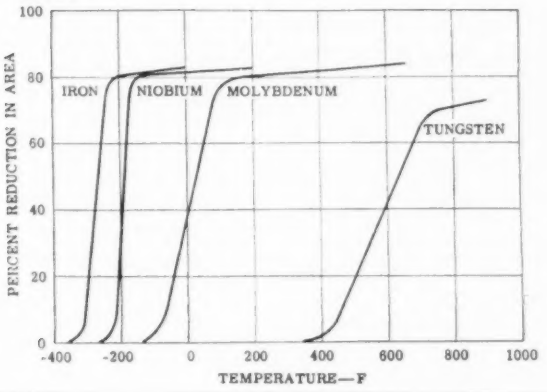


Fig. 3. Thermal Conductivity and Expansion of Molybdenum and Niobium

Properties	Molybdenum		Niobium	
	Condition	Value	Condition	Value
Thermal Conductivity BTU/Ft^2/Hr/°F/In.	212 F	800	212 F	377.5
Thermal Expansion In./In./°F x 10^{-6}	RT-1800 F	3.4	RT-1800 F	3.8

Fig. 4. Effect of Temperature on Ductility of Metals



Thermal conductivity and expansion must also be considered in design, and are often very important in determining the durability of a high temperature part. In Fig. 3 it can be seen that niobium has a higher thermal expansion and a lower conductivity than molybdenum. With respect to these properties, one element cannot be said to be "better" than the other — they are merely different. Some applications need a high heat conductivity, some require limited heat transport.

High temperature parts very often fail by thermal fatigue caused by cyclic stresses induced in the parts when they are heated and cooled. The magnitude of these thermal stresses is directly related to the thermal expansion, conductivity and elastic modulus of the material. Both molybdenum and niobium can be expected to have excellent thermal fatigue resistance because of their low coefficient of thermal expansion. Although molybdenum has a higher conductivity, niobium's lower modulus will tend to offset this and the materials should both be resistant to thermal fatigue.

Designers of aviation gas turbines require ductility in their materials, however the limiting factor in a high temperature alloy is most often the lack of ductility. In alloys of the high melting point elements a particular kind of ductility problem associated with the body centered cubic crystal structure of all of these elements is encountered. Iron, chromium, tungsten, molybdenum and niobium are all subject to a phenomenon known as the ductile-to-brittle transition,

which is dependent on grain size, impurity content, temperature and strain rate. This means that alloys of these elements are brittle and will break when cold and/or under impact loading. Metallurgists have learned to minimize this phenomenon by alloying in the case of iron and steel, but the problem is always present in the elements mentioned above.

Figure 4 shows how this ductile-to-brittle transition temperature varies for several body centered cubic elements. This is an approximate comparison only, since the actual transition temperatures vary greatly for each metal, depending on the grain size, purity and type of test. It is apparent from the graph that this type of brittleness problem will be easier to overcome with niobium than with molybdenum.

Oxidation Resistance

With the exception of special gas turbine apparatus, such as turborockets, the high temperature parts of aviation gas turbines are subject to a highly oxidizing atmosphere, but again all of the high melting elements that have been considered have practically no oxidation resistance at the temperatures of the desired applications. Molybdenum is particularly poor because its oxide, MoO_3, becomes volatile below 1000°F, and above 1450°F comes off in clouds of white smoke. From a practical standpoint, niobium is not much better, although its oxide is not volatile.

There are two approaches that can be used to overcome this difficulty. For example, the poor oxidation resistance of iron can be helped greatly by alloying it with chromium and other metals. This approach has been tried on molybdenum with no practical success. Sufficient protection of molybdenum parts has been achieved by various coatings and claddings to make it useful for many applications, but these give only temporary and somewhat unsatisfactory results. An example of one of the more successful applications of molybdenum is in turbine nozzle vanes, fabricated of Inconel-clad molybdenum sheet. Engines were tested more than 30 hr with very satisfactory results at temperatures over 2000°F.

Niobium can be protected in a similiar manner. The problem of protecting niobium is much less severe, partly because its oxide is not volatile and minute imperfections in the coating are not as deleterious. The most significant difference between molybdenum and niobium is the possibility of developing an oxidation resistant alloy of niobium with adequate mechanical properties. Several investigators have developed niobium base alloys with excellent oxidation resistance up to 2250°F.

Ease of Fabrication

If a material is to be useful for structural components it must be fabricated easily, using practical techniques. Moybdenum can be forged into useful shapes, using proper control of the temperature and amounts of reduction. It can also be rolled into bars and sheets. There is no apparent evidence of increased difficulty with niobium. One of the important aspects of proper fabrication of molybdenum is the necessity for fairly close control of residual cold work in the metal. With molybdenum of commercial quality, and with presently available alloys, a residual amount of cold work representing about 50 to 70 per cent reduction is necessary to give the required strength and ductility. Too little cold work will make the molybdenum both weak and brittle, while too much will lower the recrystallization temperature, reducing its strength at temperatures over 2000°F.

To obtain this optimum amount of cold work, molybdenum alloys must be recrystallized at the proper point in the rolling or forging cycle and final reduction to size accomplished at temperatures ranging from room temperature to 2400°F depending on the particular alloy and final product. Die design and forging sequences must be especially controlled in the manufacture of intricate forgings to assure correct amounts of reduction throughout the finished part.

The first niobium base alloys to be commercially available for structural parts will also be strain hardened, and will require controlled amounts of cold work to give them desirable properties. Limited experience with niobium alloys indicates that close control may be required until alloys are developed which do not depend on work hardening for their properties. Little is known about forging techniques, but the higher general ductility of niobium permits most rolling operations to be accomplished at or near room temperature.

Forming sheet metal is one of the most important fabrication jobs that must be considered for aviation gas turbine parts. Both molybdenum and niobium are readily formed by the normal techniques, but molybdenum often must be heated to 600 to 1000°F for severe forming. Indications are that this may not be necessary with niobium. This is not a serious disadvantage, however, because such warm working is normal practice in many magnesium and titanium fabrications.

Joining is a more serious problem. Welding by such processes as inert gas shielded arc will cause the weld metal to pick up gaseous impurities, such as nitrogen and oxygen. These can seriously embrittle both molybdenum and niobium. Many problems remain unsolved in the field of welding both molybdenum and niobium, but the embrittlement problem seems to be of a much lesser magnitude in niobium.

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NIOBIUM THEORETICAL CONSIDERATIONS

Fig. 5. Portion of Periodic Chart Showing Relative Location of Refractory Metals

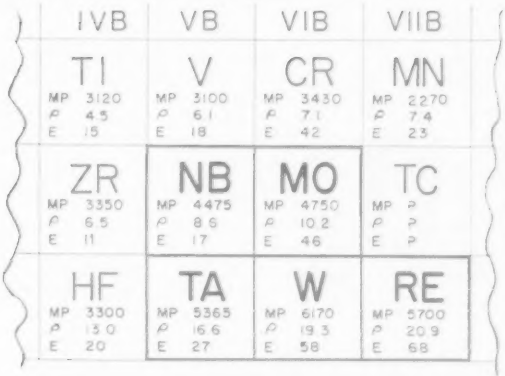


Figure 5 shows part of the Periodic Chart showing the location of the high melting refractory elements, how these elements are related, and several of their more important properties. Niobium and tantalum are in the same family, group VB, while molybdenum and tungsten are close neighbors in group VIB. Rhenium is also close by in group VIIB. As expected, niobium and tantalum are found to be very much alike in most respects. They both have lower moduli than their respective neighbors in group VIB. One very significant point is that, although tantalum has the same BCC structure, no evidence of a ductile-to-brittle transition has been found, even with rather impure material as low as —320°F. It is suspected that niobium also would be less sensitive to impurities in this respect than other refractory metals. Limited experimental work in this field tends to prove this. Embrittlement of welds from gaseous contamination and brittle behavior at low temperatures both seem to be much less of a problem with niobium than with elements of group VIB, such as Mo and W.

The advantages of the low modulus of niobium were mentioned previously. Other things being equal, a low modulus will permit more alloying without serious loss of ductility. There are two reasons why this tolerance for alloying elements is of primary importance. First, it allows high percentages of elements imparting oxidation resistance to be added to niobium without reducing ductility to an undesirable level. Secondly, it permits greater flexibility in designing alloys for high temperature strength.

Since strengthening of commercial Mo and Nb alloys by cold work is lost by recrystallization, the usable temperatures are limited by the recrystallization temperature. Also, the recrystallization temperature is lower with more cold work, thus making the strongest alloys useful at the lowest temperatures. It is most desirable, therefore, to develop alloys which are not dependent on cold work for their strength.

Creep, the problem at high temperatures, is caused by two types of dislocation movement, "glide" and "climb." It is possible to increase the resistance of a metal to creep by interfering with either or both of these types of movement. Dislocation glide can be retarded by introducing interfering particles by precipitation. This is common with conventional age-hardening alloys.

Dislocation climb, the movement of a dislocation around an interfering particle, is related to the rate of diffusion. Adding solid solution elements with low diffusion rates can be expected to slow down dislocation climb and increase creep strength.

Thus, since niobium should tolerate more alloying, it will permit the strengthening of its alloys by both important mechanisms. Therefore, it is felt that the possibilities for the development of a strong, oxidation resistant alloy are very good.

Extracted from presentation at SAE Annual Meeting.

B_2O_3 engine deposits from high-energy fuels

diborane and pentaborane cause boric-oxide deposits at alarming rates in aircraft gas turbines; engine redesign may be necessary

by Louis J. Schafer, Jr., and Robert O. Hickel

Boric oxide (B_2O_3) deposits on combustion liner number 14 of a J33-9 after 1 hr and 50 min of operation using a blend of hydrocarbon and boron fuel. Blend produced B_2O_3 at only 1/3 the rate of one proposed high energy fuel.

The presence of boric oxide in the products of combustion of high-energy boron fuels causes deposits on turbojet engine components at a rate that precludes their use at the present time.

Despite the enthusiastic reception the idea of super fuels has received in the technical and trade journals, there are some little-discussed shortcomings and deleterious effects which far outweigh the high heats of combustion which the high-energy fuels possess. The boric oxide (B_2O_3) deposits the fuels cause affect engine performance, and will necessitate a combination of engine redesign and fuel refinement before the boranes can be used operationally. The magnitude of these engine deposits, their locations in the engine, and their effects on performance must all be studied in long, tedious test-cell runs before embarking on the redesign that might lead to high energy fuels replacing or supplementing the hydrocarbons.

Two of the fuels being considered are diborane and pentaborane. The boric oxide (B_2O_3) which they produce has a low melting point but does not vaporize readily; it occurs as a liquid in the combustion process and solidifies on the relatively cool engine parts (temperatures less than 1000° F).

The formation of boric oxide has been estimated at the staggering rate of 5820 lb/hr for diborane and 7410 lb/hr for pentaborane. Rates at which build up occurs in specific engines is under investigation.

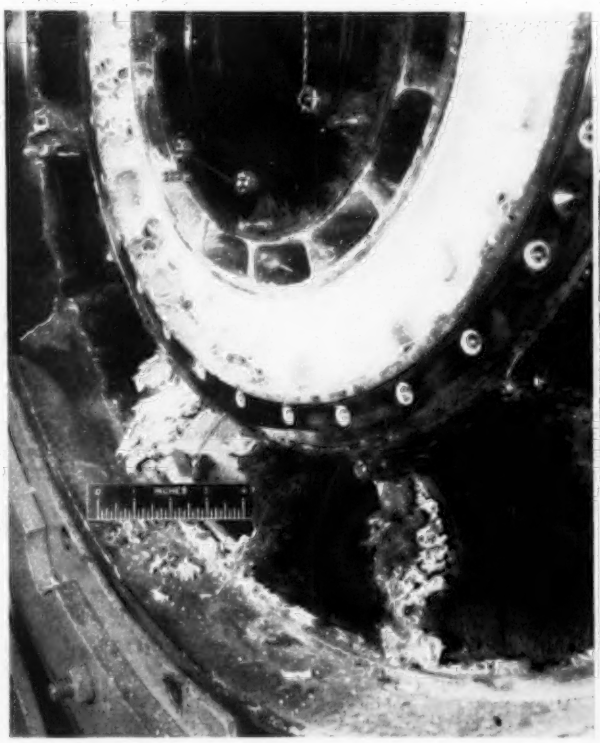
Because of some of the problems associated with obtaining and handling the high-energy fuels, most tests to date have been run with blends of hydrocarbons and borates that produce boric oxide buildup in essentially the same areas, but at lesser rates than the actual fuel. This slower buildup facilitates data collection.

What to Expect from Boron Fuels

Results of one of the most recent tests, which used a fuel mixture of 70 per cent trimethyl borate and 30 per cent methyl alcohol in a J33-9 turbojet engine, indicate that the following about high-energy boron fuels:

- Heavy deposits form on all parts exposed to combustion gases.

Continued on next page



Large lumps of B_2O_3 deposits collected at the exit of the combustors. Redesign of the combustors seems necessary if J-33 were to operate satisfactorily on high energy fuel.

Boric oxide deposits on the outer surfaces of the tail cone were about 1/4 in. thick (view looking upstream). Inner surface had similar deposits of amber colored, vitreous B_2O_3.

B_2O_3 engine deposits from high-energy fuels continued

- Deposits are heaviest on combustors and outlet screens for rear turbine-bearing cooling air.
- Deposit on turbine blades is very thin.
- Boric acid is formed at the rate of 2420 lb/hr and deposited at the rate of 33 lb/hr.
- The J33-9 cannot operate reliably on high-energy fuels without redesign.

Test Conditions

A standard, production J33-9 turbojet was used. The engine was instrumented to permit the measurement of engine speed, thrust, fuel consumption, and exhaust temperature gas. Because of the low heating value of the particular fuel blend used, it was necessary to provide a greater-than-normal fuel flow. This was accomplished by equipping the engine with dual-type fuel pump and duplex fuel nozzles.

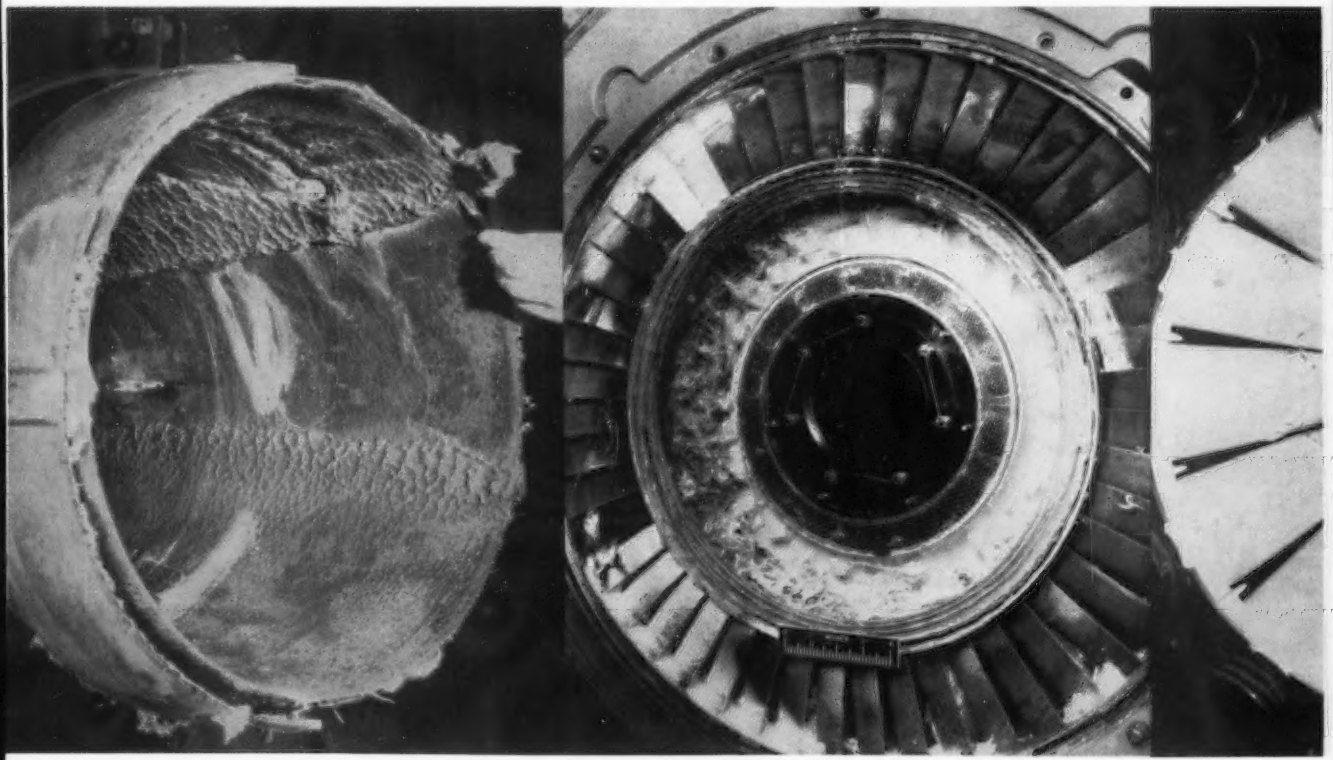
The engine was operated at 11,500 rpm, and the tail-pipe nozzle was adjusted to give a tail-pipe temperature (TPT) of 1300 F. Engine data was recorded at 10 min intervals so any change in engine performance could be detected. After 1 hr and 50 min of operation, the engine was disassembled for a more complete analysis of the results.

Test Results

Chemical analysis of deposit materials indicated that they were about 98 per cent B_2O_3, no attempt was made to determine the balance. B_2O_3 was formed at the rate of 2420 lb/hr but total accumulation was 61 lb. The rate of formation was about ½ that expected of diborane and 1/3 that expected of pentaborane, so corresponding changes in the rate of accumulation might be expected from the high-energy fuels.

Engine performance was not affected by the deposits in this test for the first 45 min of operation; after that, some mechanical difficulties were experienced in the test engine which could not be attributed to the fuel, so no conclusion as to performance could be drawn for the subsequent hour of operation.

COMBUSTOR DOMES showed the heaviest de-



Ripply, uneven deposits at exit of tailpipe were about ½ in. thick in heaviest areas

Deposits on the outlet screens in the bearing cooling-air discharge passages almost completely blocked air movement. Boric oxide would not be as severe in these areas if the aircraft were airborne, since ram air would assist dissipation.

extracted from recently-published NACA report

posits; the J-33 has 14 combustors. For an unknown reason the deposits in combustor 10 were relatively light. Crystalline deposits built up to a thickness of about ¼ in. in some areas. The fuel nozzles were imbedded in the deposits on the spinner disk, but none of the nozzle screens were plugged. There was a heavy deposit of B_2O_3 on the spark plug in dome 14, but the gap was not closed.

BURNER LINERS had deposit buildups as great as 1¼ in. Deposits of this magnitude would certainly increase the pressure drop through the combustors and might decrease combustion efficiency. It would appear that redesign of the combustor would be necessary if the J33 were to operate with high-energy fuels.

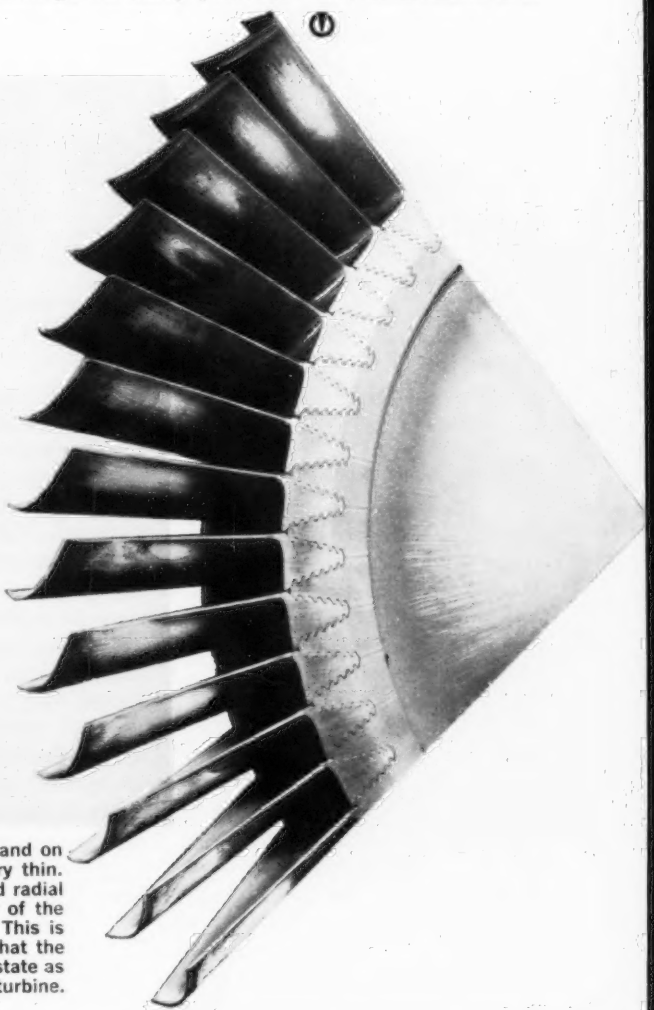
TURBINE ROTOR contained the lightest deposits. This is in accordance with the results of previous tests on other engines. The coating on the blades was a thin vitreous substance and had radial flow lines on the surfaces. This indicates that the B_2O_3 flowed along the blade length and was thrown from the blade tips in a liquid form. Indications of flow lines were also apparent on the turbine disk.

EXHAUST SECTION which contains the tail pipe, tail-pipe nozzle and tail cone had deposits up to ½ in. thick. The inside surface of the tail cone had uniform deposits of vitreous B_2O_3 up to ¼ in. thick. On the inside of the tail pipe, ripply deposits of amber colored B_2O_3 built up to ½ in.

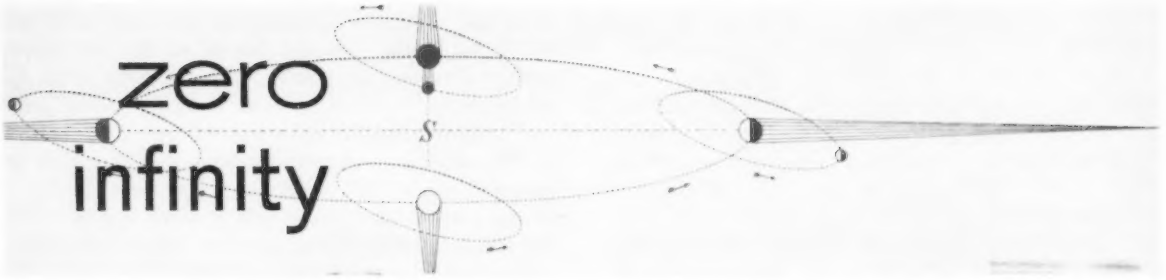
REAR TURBINE BEARING COOLING-AIR SCREENS in the J33 are in the stream of air which is pumped across the rear bearing housing. Combustion gases leaked radially inward through the gap between the stator and the rotor, and B_2O_3 deposits almost completely plugged the cooling air exit screens. This condition may not be so pronounced in an engine installation where ram air is available, but it is a condition of serious concern in static installations. The extreme buildup in this area is understandable since the cooling air causes rapid solidification of the liquid oxide. As mentioned, when temperatures drop below 1000°F rapid solidification may be expected.

Improvements in the specific fuel consumption and, hence, airplane range can be realized if fuels having heats of combustion higher than convention hydrocarbon fuels are used in jet engines. The boron fuels possess the properties necessary to furnish these higher combustion temperatures, but associated problems and shortcomings certainly preclude their immediate use.

Boric oxide deposits on the outer surface of the combustors add to aircraft weight but do not impair engine performance since they are outside the engine. View of combustor surfaces is facing radially inward.



Coatings on the turbine disc and on the rotor blades were very thin. The vitreous deposit exhibited radial flow lines from the center of the disc to the blade tips. This is rather conclusive evidence that the boric oxide was in a liquid state as it passed over the turbine.



This department is created to encourage thinking in new dimensions: thinking that is free of the often constraining influence of immediate difficulties. Technological progress is to a great extent based on departures from the conventional or the status quo. That which is considered illogical or impossible to accomplish, has and always will be so only within the limited compass of accumulated knowledge up to a particular date. Speculative thinking is man's most precious asset. It is hoped that this department will provide an outlet for such thinking and will serve to stimulate further ideas. The implications of the symbolism for this department head are that: while the immediate worth of a concept may range from nil to infinity, its true value will only be determined in the ultimate.

flying saucers

are they best for space flight?

In all quarters scientists are trying to solve the problem of getting space vehicles and their occupants safely home; satisfactory solution of this problem would bring us one step closer to manned stellar exploration. Some theoretical work has been done on this problem by Dr. W. F. Hilton, Chief Aerodynamicist at Sir W. G. Armstrong Whitworth Aircraft Ltd. At a recent symposium he outlined a scheme which apart from having factual interest, actually pleased the science-fiction writers by proving that "flying saucers" are under consideration.

TABLE 1.

Altitude ft	Atms Press lb/sq ft	Loading lb/sq ft	Density Slug/cu ft	Heating Kilowatts/sq ft	
				$\gamma = 1.4$	$\gamma = 1.66$
200,000	0.7887	605	7.246×10^{-7}	30,700	18,100
250,000	0.1453	112	1.852×10^{-7}	5,680	3,320
300,000	0.0196	15.1	2.258×10^{-8}	767	452
350,000	0.004129	3.2	3.664×10^{-9}	162	94.5
400,000	0.001212	0.9	8.62×10^{-10}	49	27.9
450,000	0.000437	0.3	2.68×10^{-10}	15	10
500,000	0.000181	0.1	9.75×10^{-11}	5	4.1

Note: Values in the table are approximate only.

Re-Entry—Two Possibilities

The velocity attained in a free fall to earth from outer space would be 7 mi/sec or about Mach 34 at sea level conditions. The body could either plunge straight towards the earth then brake by rocket power, or it could enter an orbit and carry out an aerodynamic descent. The latter method is preferable because it does not entail carrying large quantities of rocket fuel to the last stages of a journey. To get into steady orbit, speed would have to be reduced to 5 mi/sec and this could be done by aerodynamic braking provided the body was of the right shape. Entering the fringes of the atmosphere at 7 mi/sec on a tangential path, a steady acceleration of 2g's toward the center of the earth would be necessary to bend the trajectory into an orbital path. Earth will only provide 1g, therefore aerodynamic means must produce the rest.

Overall requirements for an orbital re-entry vehicle are that it shall be capable of providing high drag, a lift equal to the weight during initial re-entry stages, and that it be capable of insulating the crew from heat and loading effects. If a spherical body were used, high drag would be assured and the shape would be structurally attractive, but it would not produce lift. Streamlined rocket bodies can supply only small lift so they, too, must be avoided.

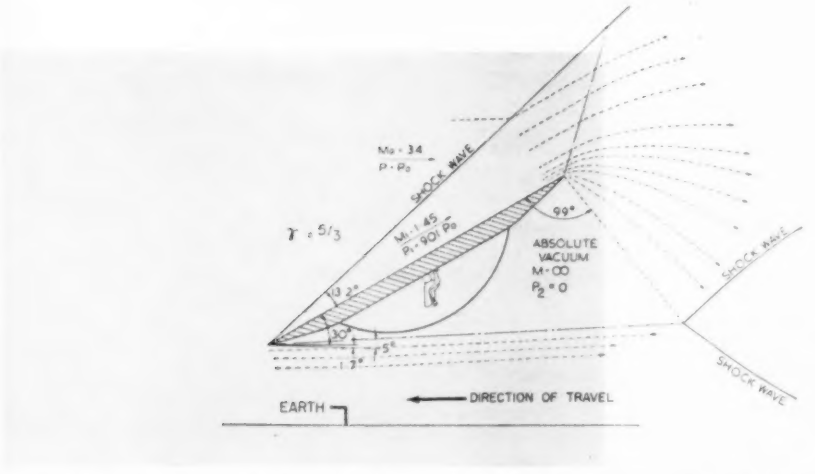
In short, a high lift, high induced drag type of body seems to fit the bill and one at once thinks of low aspect ratio wings, either square, circular or triangular in layout. Good maximum lift values are obtainable with these planes at high angles of attack and consequently high drag, but the actual shape to use

requires a little more thought. Delta wings cannot generate high lift beyond the Mach 34 line and they show no advantage over other shapes. At the very high speeds envisioned, centers of pressure should be on the center of mass for possible spin stabilization. Here a circular planform would be most advantageous and structurally possible.

Such a wing, presenting a constant depth section with knife edges, could generate large negative lift while traversing the outer atmosphere upside down at large negative incidence. By doing so a complete aerodynamic vacuum would be formed over the top surface, which would be facing downward, so that lift equal to the weight would be developed towards the earth's center. This vacuum would minimize loading on the raised crew housing, and insulate it from aerodynamic heating effects. The flat lower, or pressure surface, would be subjected to severe heating effects and would have to be designed for temperature erosion.

At Mach 34, temperatures around 50,000°C may be experienced. This raises the problem of ionized and dissociated gases. The ratio of specific heats (γ) would be nearer 1.66 than 1.4. As this quantity plays an important part in the overall design of the vehicle, the effects of speed and the appropriate γ would have to be investigated. Pressure loading would be quite appreciable but density behind all intense shock waves would be no more than four times ambient.

By means of a Prandtl-Meyer expansion, hot air on the pressure face will turn and try to fill the vacuum on the vehicle's cold side. The angles through which the expansion takes place will form parameters for fixing dimensions of the housing and gear attached to the top surface. The cross-section shown in the diagram illustrates this point by showing a possible configuration. Making the pressure dome of a smaller radius than the wing would provide added protection from the effect of the annulus. With respect to actual configuration, one must take the launching sequence into account. If the vehicle is to be launched from the earth's surface, edgewise, Mach 2.5 would be a likely compromise between rocket economy and a tolerable temperature rise. Such a launching speed would give an angle between canopy and leading edge of 30 deg if the shock waves were to be attached.



An approximation to operating altitude can be gained from a study of the angle of incidence, then resolving forces. For γ of 1.4 there would be a near uniform pressure of $1089P_0$ over the hot surface which would be at minus 45 deg incidence. Resolved, this gives a lift and drag load of $768P_0$. This negative lift must equal the weight of the vehicle to give the required 2g acceleration toward the earth. Therefore, we may equate $768P_0$ to the wing loading and observe that to keep to higher altitudes with lower pressures and heat inputs the loading must be small.

It is interesting to note that if $\gamma = 1.66$ the incidence is minus 30 deg and this gives $780P_0$, equal to the wing loading; about the same as before with regard to lift but giving a lower drag and therefore lower rate of heat input. If wing loadings around 100 lb/sq ft are employed, operating altitudes in the region of 250,000 ft are indicated.

A little variation on the re-entry flight plan is possible and the best method would have to be thought out beforehand. Effecting re-entry in one pass, about 26 deg latitude and five min flying time would be necessary to reduce speed from 7 to 5 min/sec. Heat inputs for a wing loading of 100 lb sq ft would be formidable no matter what the ratio of specific heats. In view of this it would be better to break contact after a short period and float off into space to cool off. Several braking runs could be made while getting down to steady orbit speed. At this point a roll to bring the machine right side up would prepare for the aerodynamic descent to earth. Little if any energy would be left for a cooling drift into space at this point, so the initial period of descent at positive incidence is

Continued on page 83

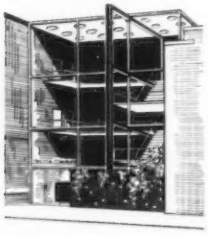
G-2

Time and again the military victory goes to the commander who is best informed—the general who knows the most about his enemy, about his flanking and supporting troops, about the terrain that lies ahead, and all the other bits of information that come from G-2, his intelligence staff.

Almost without exception, the profits and success in business go to the men who know the most about their competition, about their markets, about trends in their industry, and all the other information reported to them, faithfully and accurately, in the pages of their trade or industrial press.

★ ★ ★

Constant concern for editorial excellence is one of the main reasons for the sustained reader interest in the 16 trade and industrial magazines published by Chilton. Readers know they will find what they want and need . . . what they read will be timely and authentic. The result is an audience receptive to the products and services advertised in Chilton publications.



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DESIGN

Finding Scale Factors for Structural-Test Models.

H. D. TABAKMAN. *Mach. Des.*, (February 20, 1958), 4 pp. Reduced-scale structural models offer practical and economical solutions to problems of material selection and structural proportioning.

T53 and T58: Two Small American Turboshaft Engines.

Flight, (January 17, 1958), 5 pp. Design features and performance characteristics are discussed.

Solving Machining Problems with Chemical Milling.

A. COLTON. *Tool Engr.*, (January 1958), 6 pp. Description of process, applications, and production tolerances are given.

Cam Drum Prevents Hose Snarling During Drogue Reel Operation.

Des. News. (December 1, 1957), 2 pp. Description of the operation and design features of a detachable airborne refueling unit.

Shaft Turbine for Helicopters.

Aero, (January 10, 1958), 3 pp. The development, engineering details, and flight test results are discussed for General Electric's T58 turbine.

Missiles 1957.

Flight, (December 6, 1957), 34 pp. Comprehensive annual review of the World's guided weapons.

MATERIALS

High-Temperature Adhesives.

C. N. POWIS. *Acft. Prod.*, (March 1958), 5 pp. Materials processes and test results are given from devlopment work conducted at Aero Research Ltd., for bonding applications in high-speed aircraft.

High-Strength Steel Weldments.

B. R. ALSOBROOK. *Mach. Des.*, (February 20, 1958), 2 pp. Materials, design factors, basic applications, and heat-treatment are briefly outlined.

Design Characteristics of Titanium.

L. W. LONG. *Mach. Des.*, (February 6, 1958), 4 pp. Mechanical, physical, and corrosion properties of MST-40, -55, and -70 grades of commercially-pure titanium are presented.

"Lost Wax" Builds De-iceable Radomes.

G. MOOSING *and* C. R. DEMONS. *Amer. Mach.*, (December 2, 1957), 3 pp.
Production of glass cloth and epoxy resin radomes provided with integral connected ducting for heated air circulation.

Steel-Foil Corrugated Panels for Lightweight, High-Strength Structures.

Mach. Des., (February 20, 1958), 3 pp. Materials, design factors and properties of three types of corrugations are discussed.

PRODUCTION

Stretching the Wings of a DC-8.

O. L. RUMBLE. *Mach.*, (January 1958), 4 pp.
Equipment and methods used in contouring the dihedral break area of wing skins.

Quality Control Begins With a Gaging Policy.

R. LEGRAND. *Amer. Mach.*, (December 2, 1957), 5 pp.
Quality control setup and gag-

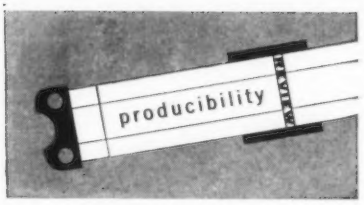
REVIEWED IN THIS ISSUE

Periodicals and Papers

Aero. The Aeroplane (British)
AMM Aircraft & Missiles Manufacturing
Acft. Prod. Aircraft Production (British)
Amer. Mach. American Machinist
Design News Design News
Flight Flight
Mach. Machinery
Mach. Des. Machine Design
Metal Progress Metal Progress
Prod. Eng. Production Engineering
Steel Steel, Penton Publishing Co.
Tool Engr. The Tool Engineer

Books Received

Exploring the Distant Stars. Putnam.
The Exterior Ballistics of Rockets. D. Van Nostrand
The Metallurgy of Vanadium. Wiley
Programs for an Electronic Digital Computer. Addison-Wesley



ing policy at Warner & Swasey aimed at cost-reduction.

Shot Peening.

H. O. FUCHS and E. R. HUTCHINSON. *Mach. Des.*, (February 6, 1958), 10 pp. Comprehensive guide for designers to the process, its applications, its effects, and how and where to specify this process.

Machining Honeycomb.

AMM, (January 1958), 4 pp. A description of the machinery and chucking process in use at Northrup Aircraft Corp. for machining honeycomb to ±0.0005 in. tolerances

Pressing Can Make Complex Shapes.

C. C. HIGGINS. *Prod. Eng.*, (January 6, 1958), 2 pp. Possibilities of utilizing combined operations, and limitations of pressing process are discussed.

When and How to Use Throw-Away Inserts for Cutting Tools.

C. H. WICK. *Mach.*, (January 1958), 15 pp.
Comprehensive treatment of the types, applications and limitations of throw-away inserts.

Tool Design for Machining Magnesium.

Tool Engr., (January 1958), 4 pp. Tool design features are suggested for turning, milling, drilling, reaming, sawing, threading, and counterboring.

Heavy Press Forgings for Aircraft.

E. C. WRIGHT. *Metal Progress*, (December 1957), 6 pp. The advantages of producing small forgings on 35,000 to 50,000 ton capacity presses are aired. Closer tolerances would be possible; author claims weight reductions to one-half and machining time reductions to one-eighth are possible.

Calculating Economic Cutting Speeds.

F. J. GALLAGHER. *Tool Engr.*, (January 1958), 5 pp. Formula given to determine optimum economic speeds for metal-cutting operations.

The DC-8 in Production.

Aero, (January 17, 1958), 4 pp. General illustrated description of production methods.

Fabricating the Redstone Missile.

Steel, (January 20, 1958), 6 pp. Manufacturing methods, companies, and the materials used in certain components are discussed.

Rotation of Optical Wedge Measures Gage-Block Parallelism.

Des. News. (December 1, 1957), 2 pp. Optical system developed by the National Bureau of Standards enables a standard interferometer to give direct readings of nonparallelism of gage-block surfaces, within 2 millionths of an inch.

BOOKS RECEIVED

The Exterior Ballistics of Rockets.

LEVERETT DAVIS, JR., JAMES W. FOLLIN, JR., and LEON BLITZER. D. Van Nostrand, 1958. The authors develop the basic theories and equations which govern rockets without moving control surfaces. Unfamiliar concepts that go beyond vector analysis and differential equations are explained in detail.

Programs for an Electronic Digital Computer.

M. V. WILKES, D. J. WHEELER, and STANLEY GILL. Addison-Wesley, 1957. Second edition of a 1951 book, revised to include machines other than the Electronic Delay Storage Automatic Computer (EDSAC). It is written for those putting machines into operation and those wishing to assess the possible applications of such machines in their own problems. The order code of EDSAC is used in developing the text.

Exploring the Distant Stars.

C. B. CLASON. Putnam, 1958, 384 pp. $5.00. This book is written for the layman who cannot always understand the more specialized books of the professional astronomers, yet wishes to follow at least some of the mental processes through which astronomers draw their startling conclusions about the nature of stars and the universe. Although our solar system is discussed in some detail, there is special emphasis placed also on the distant stars and galaxies.

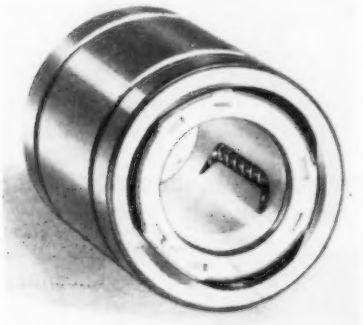
The Metallurgy of Vanadium.

W. ROSTOKER. Wiley, 1958, 185 pp. $8.50. This book offers a full discussion of the state of the art of vanadium production and alloying. It provides a comprehensive treatment of the extraction, properties, and processing methods, and serves as a ready reference for those who consider new materials for special applications.

materials / components

Accelerometer Bearings Available for Application In Other Components

A linear type bearing designed for use in accelerometers of inertial guidance systems is now available for super-sensitive applications in other instruments, controls, and vital components where low friction linear motion is desired.



The construction of the new bearing provides "through passages" between the ball retainer and the outer sleeve. These passages are in register with the relief side of each ball circuit and permit cleaning solvents to be blown through which also allows the escape of dust particles from both the outside and inside of the retainer.

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The outer sleeve and balls are made of AISI 52100 steel and the retainer of brass, but when required, bearings can be furnished made entirely of stainless steel.

Thomson Industries Inc.

Circle 176 on postcard for more data

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Vyflex Fligid, a polyvinyl chloride (unplasticized), is said to protect base materials of both ferrous and non-ferrous metals from corrosive attack by a line of chemicals ranging from concentrated oxidizing acids to highly concentrated alkalies.

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Joints between individual panels or sections of the lining are hot-gar-welded with an unplasticized polyvinyl chloride filler rod or strip.

Wagner Bros., Inc.

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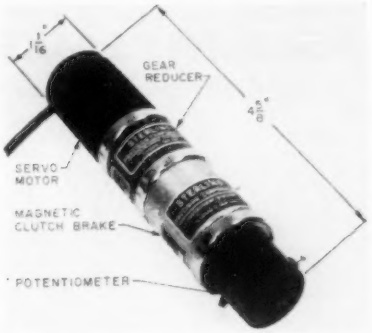
Compact Servo-Package Has Low Braking Time

A compact servo-package combining a servo motor, a geared reducer, a magnetic clutch-brake, and a potentiometer has recently been made available. In this particular unit, the motor drives the potentiometer arm at a speed corresponding to the rotation of a radar scanning antenna (approximately 40 rpm). Upon a given signal the motor is uncoupled and the potentiometer is braked within two milliseconds.



Sterling Precision Corp.

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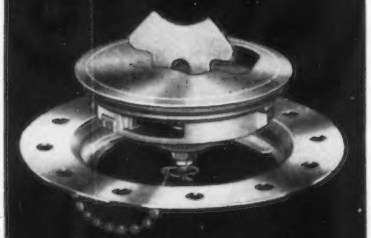

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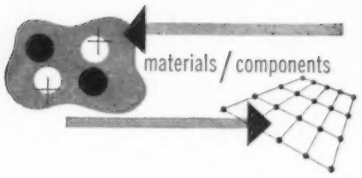
Circle 6 on Inquiry Card, page 65



jet pump, a pressure sensitive shut-off-valve, and a check valve. The unit functions to "boot-strap" pressurize a hydraulic reservoir and pump suction by use of pump discharge pressure.

Valves pressurize a 1000 cu in. reservoir trapped air volume to 10 psig in 20 sec, 20 psig in 30 sec, 30 psig in one min, and 40 psig in one min and 40 sec, starting with zero reservoir pressure at sea level.

Vinson Manufacturing Co.

Circle 178 on postcard for more data

Transducer Measures Small Angular Position Changes

A single coil variable reluctance angular position transducer has applications wherever exact measurement of small an-

gular position changes, and high resistance to shock and vibration, is required.

Gauge specifications require it to withstand 18 impact shocks of 30 g's with an impulse having a duration of 11 ±1 milliseconds (six shocks in each of three major axes) without damage and without exceeding normal operating tolerances. Operating temperature range is —65 to 250°F.

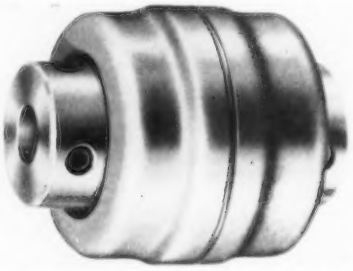
Ultradyne, Inc.

Circle 177 on postcard for more data

Coupling for Miniature Devices Has Steel Bearings and Raceways

Metro-flex couplings will handle: (1) angular misalignment of driving and driven shafts up to five deg, (2) parallel offset to as much as 0.010 in., and (3) axial end play up to 0.090 in.

Hardened steel balls and raceways give low friction trans-



mission of torque or positional information. The bearings are lubricated and sealed at the factory.

The couplings are used with servo-mechanisms, computers, tachometer takeoffs, oscillographs, or wherever two shafts of small devices need to be coupled.

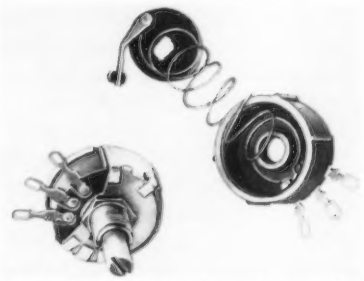
Metron Instrument Co.

Circle 179 on postcard for more data

Molded Potentiometer Design Has Reduced Noise Level

The elimination of the wiper arm collector by use of a beryllium copper spring between the contact arm and the center terminal greatly reduce the electrical noise in a molded composition potentiometer.

One moving point of con-

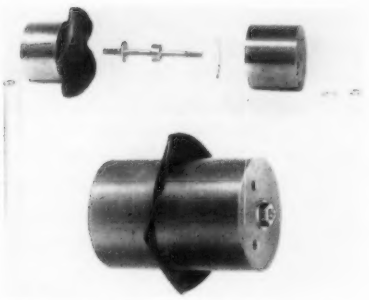


tact, the carbon brush, on the resistance element reduces the noise to less than one-half and

extends the rotational life of the potentiometer to over a million cycles. An overall resistance change of approximately 6.3 per cent is average.

Reon Resistor Corp.

Circle 180 on postcard for more data



Phenolic Bonding Cement Used in Assembly of Water Regulator Diaphragm

Ray-BOND R-81114, a synthetic-rubber phenolic-resin-base bonding cement which resists attack by jet fuels, is being used for assembling the seal of water-injection regulator supports, instead of pinching the seal into the seat.

It has an operating temperature range of —65 to 400°F.

Raybestos Manhattan, Inc.

Circle 175 on postcard for more data

Silicone Compound Used For High Temperature Seals

Silicone rubber compound Number 85-138 is a new material for "O" rings and custom molded parts for high temperature sealing applications.

The compound is recommended for applications as high as 600°F for short periods of time. It has a tensile strength of about 800 psi and an elongation of about 250 per cent.

Compression set after 24 hr at 450°F is approximately 25 per cent. After air-aging at 600°F for 48 hr, tensile loss is about 35 per cent, elongation is 59 per cent, and hardness increase is 15 deg Shore A.

Parker-Hannifin Corp.

Circle 173 on postcard for more data

Operating Temperatures of Grease Extended to 600° F

To meet the high speed and high temperature lubrication requirements of supersonic aircraft and missiles two greases with an operating range from —45° to 600°F, have been developed.

Designated grades ETR Grease B and ETR Grease D, the lubricant is regarded as meeting most of the present requirements for extreme high temperature lubrication of anti-friction bearings.

At 450°F the bearing performance of the grease will surpass the 500 hr minimum required by MIL-G-25013.

Shell Oil Co.

Circle 193 on postcard for more data

Foam-in-place Material Used in Sandwich Structure

Thermofoam 607, Type 1, a liquid foam-in-place material, is intended for the reinforcement of honeycomb sandwich structures, for filling voids in metal or reinforced plastic structures, and for providing attachment points in sandwich structures. The service range of the foam is from —70 to 500°F.

After mixing its two components and curing, the expanded foam has the following properties:

Density—25-40 lb per cu ft.

Compressive strength—1100-2000 psi.

When used in foamed-in-place applications, and when the properties given are required, Thermofoam 607, Type 1, must be confined while curing.

Aerobond

Circle 171 on postcard for more data

Actuator Has Gear Ratio of 30,000 to 1 Weighs Only ¾ Pound

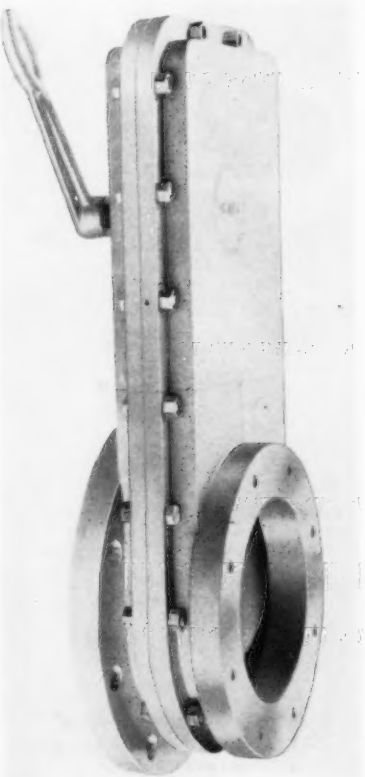
An actuator three in. long and weighing ¾ lb has been designed to open and close air duct shutters on a turboprop airliner, for ground cooling the plane's cabin.

Featuring a gear ratio of 30,000 to 1, the small actuator can supply up to 100 in. lb of torque. Two stages of compound planetary gears, arranged in a cavity only one-half in. deep, permit the high ratio, which can be modified to a 50,000 to 1 level.

A 115-v motor, of single phase, 400 cycle ac type with integral starting capacitor provides the power for the actuator.

Garrett Corp.

Circle 182 on postcard for more data



Six Inch High Vacuum Valve Has Varied Flange Sizes

Systems designers can select flanging compatible with other components, without requiring special adaptors, or extra fittings, on a new six inch high vacuum valve.

Four standard flange combinations are available from stock.

The valve (VG-106T) is a quick-acting type, with an unobstructed, straight-through open-

Rate Gyros

by Gyro Dynamics are highly sensitive instruments utilizing the flotation concept of design. Precision-built they are smaller, lighter and capable of maintaining the highest degree of accuracy through extremes of shock and temperature.

As a result, these rate gyros have been qualified as an integral part of flight test and stability augmentation systems of many current missile and aircraft programs.

Standard Miniature
Designed for applications —in AC or DC—where high vibrational or accelerational "G" loads are expected.

Sub-miniature
Smaller version of AC rate gyro capable of operating directly from 115V. No transformer or choke coil required because of high "Q" design. Damping: .4 to 1.0: Temp: —40°F to +165°F.

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TWO-AXIS FREE GYRO

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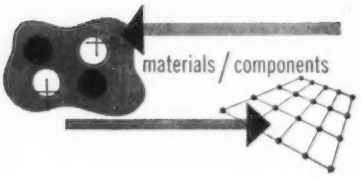


ing. The slide action is actuated by a half-circle handle turn. There is no valve disc contact until fully closed; the closing action is a ball-and-socket principle with no pins to shear.

Vacuum Research Co.

Circle 189 on postcard for more data

Subminiature Gyro Can Withstand 100 G Shock

A subminiature floated rate gyro with dynamically balanced hysteresis motor is capable of withstanding a 100 g shock, and 2000 cps at 15 g's vibration in any axis.

Controlled uniform damping is accomplished by varying the shear damping area using the damping medium, as a sensing device.

The gyro is two in. long, has a 15/16 in. diam, weighs three oz and is designed for missile and aircraft application as a control and stabilization element.

Fairchild Controls Corp.

Circle 184 on postcard for more data

Half-Inch Poppet Valve Regulates Pressure of 3,000 PSI to 15 PSI ±1/2

A half-inch poppet, single stage, helium regulator for missile applications is capable of regulating pressures in excess of 3,000 psi down to 15 psi with a control of plus or minus one-half psi while being subjected to low temperatures.

Other design features include: minimum vent bleed off, an established reference pressure applied to a double diaphragm construction, and small package volume of 6 x 10 x 5 in. weighing seven lb.

Garrett Corp.

Circle 191 on postcard for more data

Silicone Resin Acts As Paint and Baking Enamel Additive

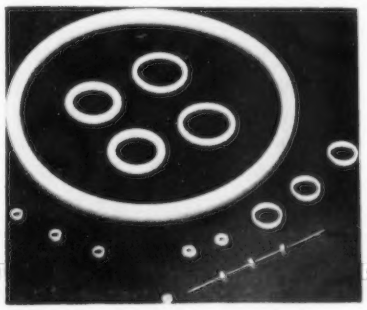
A silicone resin designed for cold-blending with alkyd, melamine, and acrylic type baking enamels to give them improved color and gloss retention, thermal stability, and resistance to weathering has been made available under the designator R-64 silicone.

This resin is expected to find use as a base for aluminum paints to operate in the 500° to 1200° F range as a protective coating for aircraft engines and exhaust stacks.

Some applications already developed include external coatings for space heaters, furnaces, and exhaust systems, and as enamels for transformers and motors, high temperature lamps, radio tubes, and electrical components and appliances.

Union Carbide Corp.

Circle 183 on postcard for more data



Teflon O and V Ring Seals Have Close Tolerances

Teflon seals with dimensional tolerances of 0.0001 in. are available from Tri-Point Plastics, Inc.

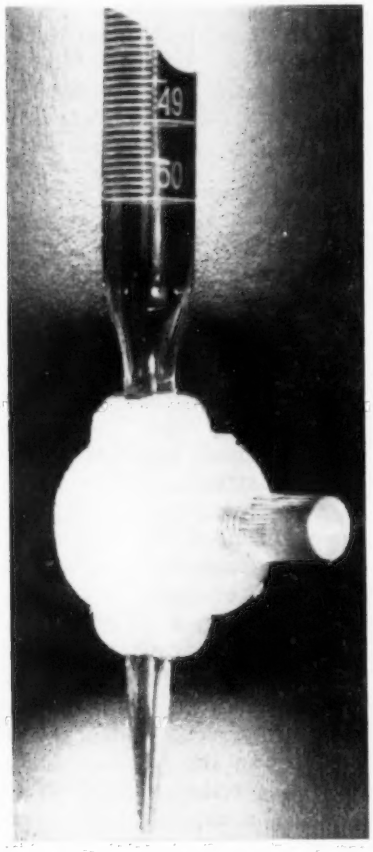
Sizes are presently limited to a maximum O.D. of 15/16 in., and a maximum I.D. of 3/4 in. With new machining techniques, wall thicknesses can be kept to 0.062 in. on production lots and to 0.012 in. on small development lots. Dimensions can be held to 0.001 in. in certain designs.

Tri-Point Plastics Inc.

Circle 190 on postcard for more data

POLYETHYLENE DIAPHRAGM ASSURES DELICATE CONTROL

A stopcock for laboratory application provides delicate control of the flow of liquids and gases. It is designed to be completely non-sticky in operation.



The Tapnik diaphragm stopcocks eliminate jamming experienced with needle-valve types.

Tapered holes in the tap body are of a special shape to give a very powerful grip on the ground glass tapers which are forced into them.

For normal operation with liquids, the Tapnik can be used with either the Neoprene or Polyethylene diaphragms. For use with gas, the Neoprene diaphragm is essential to give complete gas tightness.

General Laboratories Supply Co.

Circle 136 on postcard for more data

ADJUSTABLE CAM ASSEMBLY DESIGNED FOR SERVOS

An adjustable cam assembly designed for use in servo mechanisms, where it is desired to actuate switches and similar devices at predetermined angular limits, has been announced.

Two stainless steel cams may be rotated relative to each other to permit adjustment between rise from 0 to 180 deg. A balanced clamp secures the assembly to the shaft as well as locking the cams for the desired setting.

Maximum diameter is 1⅛ in. and hubs are available for ⅛, 3/16, and ¼-in. shafts.

Sterling Precision Corp.

Circle 138 on postcard for more data

GRINDING TECHNIQUE SAVES TIME AND MONEY

A precision grinding technique, accurate to 0.0001 in., has reduced overall manufacturing costs and as much as doubled production rates on servo valve parts in manufacturing the F8U Crusader. The new grinding technique permits extremely close matching of servo valve pistons and cylinders.

This production grinding utilizes Multiform grinders that

shape circumferential contours from alloy bar stock with Crushtrue abrasive wheels. The ports are machined by the ultrasonic method using Cavitron equipment. The critical final grind-to-match utilizes a Model 121-C Micro-Form grinder with an extended work table and tandem optical system.

The finish grind is accomplished through simultaneous optical comparison of each cylinder port and its corresponding piston land.

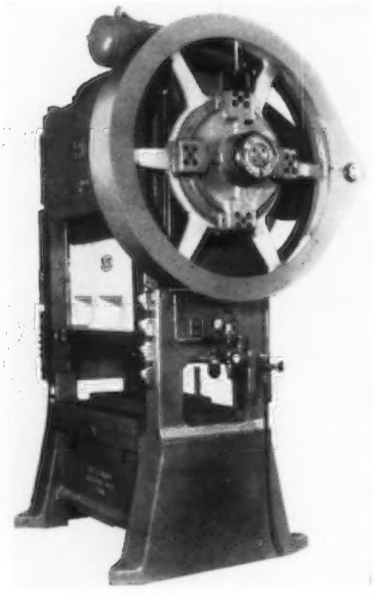
Before utilization of this high precision grinding technique, both parts had to be ground separately.

Sheffield Corp.

Circle 149 on postcard for more data

TORQUE LIMITOR PROTECTS PRESSES FROM OVERLOADS

An electro-magnetic torque limiting device, which protects presses against dangerous overloads through the press cycle, is now available. It has been tested under actual production shop conditions over an extended period of constant usage.



The unit can be installed on the crankshaft, or on the back-shaft, of any mechanical press. The crankshaft mounting is preferred where possible. It functions as a protective "kickout" by disengaging the crankshaft from the flywheel and drive when work tonnage exceeds the preset limit at any point in the press stroke.

E. W. Bliss Co.

Circle 145 on postcard for more data

FAN SAVES WEIGHT ON HELICOPTER ENGINE

A lighter axial flow fan now in use for cooling engine oil on several makes of helicopters has been developed. A special design featuring light-alloy metal construction permits weight

savings of 23 per cent while maintaining the same external dimensions as previous models.

The fan weighs 17 lb and is rated at 4650 cfm. It requires 7.3 hp and is driven by a timing V-belt from a shaft connected to the helicopter engine. The rotor tip diameter is 14 in.

Borg-Warner Corp.

Circle 134 on postcard for more data

ELECTROPLATERS SAVE TIME WITH Na Cu Cn DOUBLE SALT

Use of sodium-copper cyanide double salt by eletroplaters facilitates the make-up or replenishment of plating solutions by eliminating the several steps required to dissolve copper cyanide properly. Its use also reduces handling of chemicals, and avoids errors in make-up or replenishment of the plating bath which, because of its high purity, results in a high-quality finished product.

Du Pont Electrochemicals Dept.

Circle 150 on postcard for more data

SOFT OR HARD MATERIALS SAWED AT HIGH SPEED

Continuous high-speed cutting, without overheating, in materials ranging from soft wood to stainless steel is claimed for the Supreme model Handy Angle Saw just introduced.

The unit is a redesign of a lightweight reciprocating saw

used in manufacturing and fixed-base maintenance. Major innovations include new case design that improves lubrication, anti-friction bearings throughout, and heat-treated, hardened-and-polished material for all wearing parts.

Price & Rutzebeck

Circle 147 on postcard for more data

PORTABLE INSPECTION KIT HAS FLUORESCENT PENETRANT

A completely portable fluorescent penetrant inspection kit is available for locating cracks, pores, leaks, and other defects open to the surface in any solid material. This kit, known as the Zyglo ZA-43, contains the most sensitive of the Zyglo materials, all in push-button, pressurized spray cans.

Included in the steel carrying case are pressurized spray cans of cleaner, penetrant, and developer; a 100 watt high intensity black light; cleaning cloths; wire brush; and detailed instructions.

In testing, penetrant is sprayed on the surface of the part to be tested, and time is allowed for capillary action to

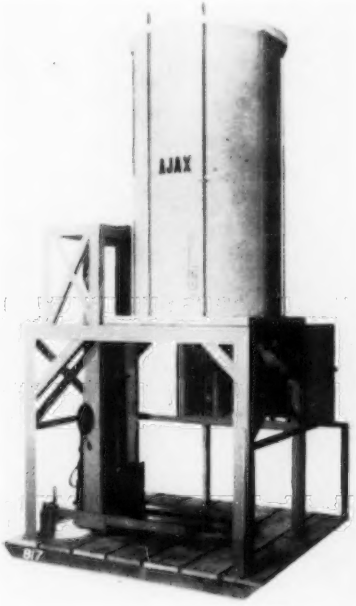
draw the penetrant into any crack or porosity. Cleaner is then used to remove penetrant from the surface. By applying a thin film of spray-on developer, the fluorescent penetrant is drawn to the surface from any crack or pore. The portable (115-v) high-intensity black light locates every defect as a glowing fluorescent indication.

Magnaflux Corp.

Circle 151 on postcard for more data

CARBIDE SINTERING FURNACE LOADS FROM BOTTOM

Significant production savings are built into a unique carbide sintering furnace just



introduced, the new model includes several departures from conventional techniques.

Based on proved high temperature advantages of high frequency induction heat, the furnace introduces a number of additional advantages through its design for bottom loading. A platform swings out for fast and convenient loadings, then swings back beneath the furnace. At this point, a hydraulic lift goes into action, carrying the material up and into the furnace.

This type furnace can be operated at temperatures upward of 2500°C, and under special atmospheres, if desired.

Ajax Electrothermic Corp.

Circle 135 on postcard for more data

VIBRATIONS PINPOINTED AND 'BALANCED-OUT' BY ANALYZER

Model 600 vibration analyzer and portable balancer provides instrumentation to measure amplitude from 0.1 to 100 mils, velocity from 0.03 to 30.0 in/sec, and frequency from 450 to 150,000 cpm (continuously variable filter permits separate analysis of each frequency). To pinpoint cause of predominant vibration, a velocity type pickup is provided, as well as a stroboscopic lamp to visually study a rotating part. There are jacks for oscilloscope and strip-chart recorder.

Int'l Research & Development Corp.

Circle 148 on postcard for more data

TOOL BURRS AND CHAMFERS HOLES IN BLIND CAVITIES

Noburmatic "H" tool was developed to meet the need for a tool which would function with a positive mechanical action, and at the same time be automatically self-actuated.

It is an ideal tool for deburring and chamfering both front and back sides of holes (1) where manufacturing procedure is facilitated by a tool which will finish both faces from but a single entry without need for reversing the part, (2) drilled into a blind cavity where the back face is not openly exposed, (3) line drilled through two or more parallel walls.

The tool is rugged, positive acting, and automatically

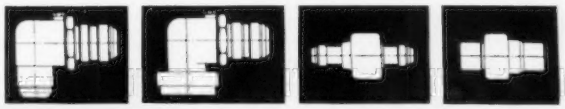
DOWN-TO-EARTH FACTS...

about SEALOL swivel joints

10 inch-pounds swiveling torque at 3000 PSI

Military Specification MIL-J-5513A allows 120 inch-pounds of torque on swivel joints like that shown. In both Type I and Type II Systems, the extremely low swiveling torque (10 inch-pounds at 3000 PSI) of these Sealol units makes more hydraulic power available for the service intended. All Sealol Aircraft Swivel Joints are designed to meet and exceed your most exacting specifications . . . for minimum torque and maximum leak-free life. Ask us to prove it!

TYPICAL CUSTOM-DESIGNED SEALOL SWIVEL JOINTS



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Circle 8 on Inquiry Card, page 65

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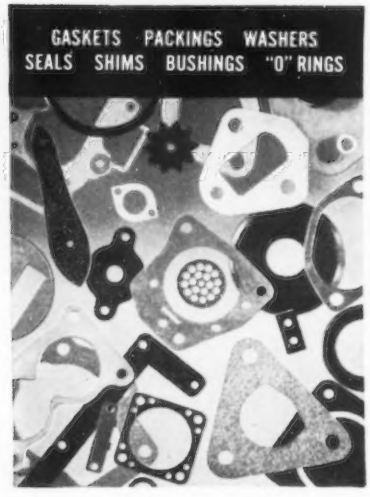

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Put our 87 years experience to work for you—Auburn's engineers are tops in their field in designing and fabricating precision sealing devices. Their know-how is at your command. "O" Rings are a speciality with us.

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Circle 9 on Inquiry Card, page 65

self-actuating. It does not depend on any spring setting. It is designed to be employed to maximum advantage in mechanized, or automated machine tools. It is equally adaptable to manual usage in conventional drill presses and in sequence with drilling operations. An approximate 45 degrees chamfer angle is produced. It is available for hole sizes ranging from ¼ to ¾ in. and for working depth from 1½ to 3¼ in.

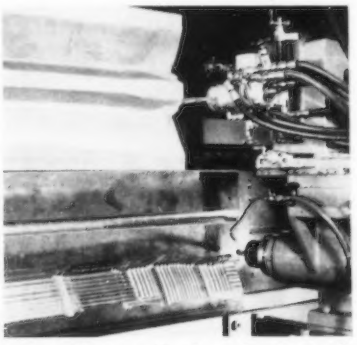
Nobur Mfg. Co.

Circle 152 on postcard for more data

SCULPTURE MACHINE USES HYDRAULIC DRIVE

Hydraulically driven sculpture machines for easier and faster tracer-controlled contour and profile milling are available.

The machines are driven by a variable-speed hydraulic motor. Reduction gears provide spindle speeds from 36 to 1900 rpm. A heavy main column con-



tains the vertical and "in-and-out" feed movement. Cutter, stylus, controls, and adjustments are located where they can easily be seen and reached. The vertical slide is a large, heavy, and extremely rigid component designed for high metal removal capacity. For the utmost in sensitivity the counter-balanced slide moves in hardened and ground ways. Both the work and the template mounting is on the vertical face of the ram. The machine base is a rigid weldment reinforced with heavy internal ribbing to provide freedom from vibration and distortion.

A wide range of metals, including the latest high-temperature and high-strength alloys, can be worked with consistent accuracy. Jobs as long as an aircraft wing spar or as compact as small forming dies can be handled. Small-size work can be machined side by side.

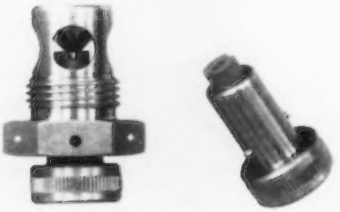
The machines are suitable for work from rough cutting to finish machining. True three-dimensional duplicaton is possible at maximum speeds and feeds for the material being machined.

Colonial Broach and Machine Co.

Circle 153 on postcard for more data

MAGNETIC DRAIN PLUG HAS BAYONET TYPE CLOSURE

To eliminate the need for tools in maintenance inspection of gear cases and similar hous-



ings, a new self-closing magnetic drain plug has been produced. It uses a bayonet type closure instead of nut and threads.

A knurled circular knob is provided which, when pushed in and given a one-quarter turn, instantly inserts or removes the magnetic plug.

These plugs are designed to meet the specifications for military and commercial aircraft. They are particularly useful for cold weather operations, and are suitable for industrial applications in general. When

Continued on page 69

for full facts on

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YOUR NAME ..... TITLE .....

COMPANY .....

PLANT ADDRESS .....

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advertisers in this issue

In order to obtain further details on items advertised or described in this issue, circle the key number (s) on the postpaid card and mail it.

9 **Auburn Mfg. Co.**
Sealing device, precision

25 **Burgmaster Corp.**
Drill, bench model turret

3 **Darco Industries, Inc.**
Flotrusion Process

7 **Darco Industries, Inc.**
Rate gyros

2 **Electric Steel Foundry Co.**
Castings, centrifugal

23 **Electro Tec Corp.**
Miniature slip rings

5 **Gabb Special Products, Inc.**
Tank Filler Cap

1 **Gear Grinding Machine Co.**
Grinders, precision

10 **Hunter Mfg. Co.**
Space heaters

19 **Kaman Aircraft Corp.**
Housings & chassis for airborne electronics

21 **Pennsylvania Dept. of Commerce**
Plant locations

20 **Quality Control Corp.**
Precision components

8 **Sealol Corp.**
Custom-designed swivel joints

4 **Sharon Steel Corp.**
Specialty steels

11 **Sonnet Tool & Mfg. Co.**
Contour cutters

12 **Sturtevant Co., P. A.**
Torque wrench

24 **Titan Tool Co.**
Stud drivers and pullers

22 **U. S. Flexible Tubing Co.**
Stainless flexducts & bellows

6 **X-acto, Inc.**
Inudustrial cutting tools

MATERIALS & COMPONENTS

Alphabetical List of Products

182 **Actuator, duct-shutter**
The Garrett Corp.

176 **Bearing, linear, ball**
Thomson Industries, Inc.

175 **Cement, phenolic-bonding**
Raybestos-Manhattan, Inc.

179 **Coupling, shaft**
Metron Instrument Co.

171 **Foam, filler and reinforcement**
Aerobond

193 **Grease, high-temperature**
Shell Oil Co.

184 **Gyro, rate, subminiature**
Fairchild Corp.

180 **Potentiometer**
Reon Resistor Corp.

178 **Relief valve, self-regulating**
Vinson Manufacturing Co.

173 **Sealing compound**
Parker-Hannifin Corp.

190 **Seals, O and V ring**
Tri-Point Plastics, Inc.

174 **Servo-package**
Sterling Precision Corp.

188 **Suspension cord, elastic**
William H. Snow Co.

177 **Transducer, angular position**
Ultradyne, Inc.

191 **Valve, poppet**
AiResearch Manufacturing

189 **Valve, vacuum**
Vacuum Research Co.

Alphabetical List of Companies

171 **Aerobond**
Foam, filler, and reinforcement

191 **AiResearch Manufacturing Co.**
Valve, poppet

184 **Fairchild Corp.**
Gyro, rate, subminiature

182 **The Garrett Corp.**
Actuator, duct-shutter

179 **Metron Intrument Co.**
Coupling, shaft

173 **Parker-Hannifin Corp.**
Sealing compound

175 **Raybestos-Manhattan, Inc.**
Cement, phenolic-bonding

180 **Reon Resistor Corp.**
Potentiometer

193 **Shell Oil Co.**
Grease, high-temperature

188 **William H. Snow Co.**
Suspension cord, elastic

174 **Sterling Precision Corp.**
Servo-package

176 **Thomson Industries, Inc.**
Bearing, linear, ball

190 **Tri-Point Plastics, Inc.**
Seals, O and V ring

177 **Ultradyne, Inc.**
Transducer, angular, position

189 **Vacuum Research Co.**
Valve, vacuum

178 **Vinson Manufacturing Co.**
Relief valve, self-regulating

NEW FOR PRODUCTION

Alphabetical List of Products

138 **Cam assembly, adjustable**
Sterling Precision Corp.

155 **Coil winding machine**
Geo. Stevens Mfg. Co., Inc.

143 **Counters, electro-mechanical**
Digitac, Inc.

139 **Drain plug, magnetic**
Technical Development Co.

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P. O. Box 74,
Village Station,
New York 14, N. Y.

Readers Service Dept.

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134 **Fan, axial flow**
Borg-Warner Corp.
135 **Furnace, sintering, carbide**
Ajax Electrothermic Corp.
149 **Grinders, precision**
Sheffield Corp.
151 **Inspection kit, penetrant**
Magnaflux Corp.
150 **Na Cu cyanide double salt**
Du Pont Electrochemicals Dept.
142 **Ratiometer**
Wallace O. Leonard, Inc.
137 **Resistor, variable**
Chicago Telephone Supply Corp.
147 **Saw, power, hand**
Price & Rutzbeck
153 **Sculpture machine, tracer-controlled**
Colonial Broach and Machine Co.
136 **Stopcock, diaphragm**
General Laboratories Supply Co.
154 **Testing machine, compression and tension**
Baldwin-Lima-Hamilton Corp.
152 **Tool, deburring and chamfering**
Nobur Mfg. Co.
145 **Torque limiting device**
E. W. Bliss Co.
148 **Vibration analyzer and balancer**
Internat'l Research and Devel. Corp.
140 **Work platform**
Atlas Industrial Corp.

Alphabetical List of Companies

135 **Ajax Electrothermic Corp.**
Furnace, sintering, carbide
140 **Atlas Industrial Corp.**
Work platform
154 **Baldwin-Lima-Hamilton Corp.**
Testing machine, compression and tension
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138 **Sterling Precision Corp.**
Cam assembly, adjustable
155 **Geo. Stevens Mfg. Co., Inc.**
Coil winding machine
139 **Technical Development Co.**
Drain plug, magnetic

APRIL 1958 ●

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Specific Products Manufactured .....

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WORTH ASKING FOR

Alphabetical List of Items

283
Accelerometers
Donner Scientific Co.

282
Assemblies & components, electrical
Gray Manufacturing Co.

280
Brazing
American Silver Co.

292
Casting
Alloy Steel Casting Co.

291
Coating, protective
American Chemical Paint Co.

288
Couplings, miniature
Thomas Flexible Coupling Co.

300
Films, 16-mm sound
Battelle Memorial Institute

284
Fork-lift trucks
Elwell-Parker Electric Co.

294
Gages, measurement
Freeland Gauge Co.

281
Gages, measurement
Mueller Laboratory

285
Indicator, elapsed time; loadmeter
DeJur-Amsco Corp.

299
Irons, soldering
General Electric Co.

296
Jigs and fixtures
Northwestern Tool & Engineering Co.

279
Laboratory furnaces
Selas Corp. of America

298
Plastic, reinforced
H. I. Thompson Fiber Glass Co.

289
Presses, metalworking
E. W. Bliss Co.

287
Rivets, blind, drive-pin
Deutsch Fastener Corp.

295
Transformer, pulse, subminiature
Pulse Engineering Inc.

297
Tubing, metal joint
Aeroquip Corp.

286
Valve, pneumatic selector
Aircraft Products Co.

293
Vibration generations systems
MB Manufacturing Co.

290
Wire, thermocouple
Thermo Electric Co., Inc.

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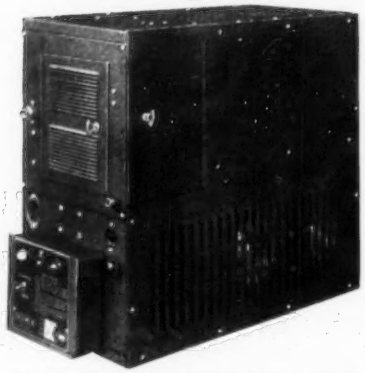
P. O. Box 74,
Village Station,
Readers Service Dept. **New York 14, N. Y.**

for mobile and portable military shelters



- designed and produced in accordance with military specifications for space, equipment and personnel heating requirements.
- 5 basic models — each custom-engineered for a wide variety of applications — for ground control and maintenance equipment in missile systems, radar, microwave and radio communication systems, etc.
- BTU/Hour range: from 15,000 to 60,000.
- multi-fuel-burning models; also models which burn any type gasoline.
- all models air-circulating, thermostatically controlled, all designed for cold starts as low as — 65°F.

Other Hunter equipment for military applications: engine heaters; unpowered, instant lighting torches; refrigeration units.

GET THESE BROCHURES TODAY!

for complete specifications and details

MH-162 "Hunter Space and Personnel Heaters"

MH-166 "Hunter Engine Heaters"

MH-167 "Hunter Instant Lighting Torches"

HUNTER MANUFACTURING CO.
30537 AURORA RD.
SOLON, OHIO

HEATING AND REFRIGERATION SYSTEMS

Circle 10 on Inquiry Card, page 65

Continued from page 64

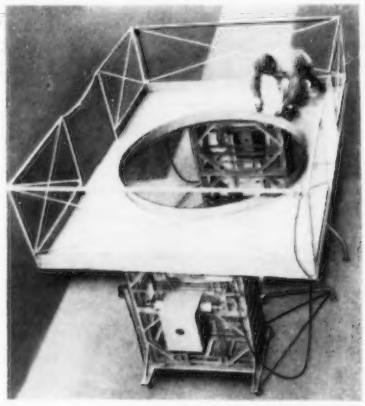
the plug insert is removed, a self-closing valve immediately seals off the opening preventing any loss of oil. A drain line with a similar bayonet connection is available.

Technical Development Co.

Circle 139 on postcard for more data

WORK STAND MADE UP OF TWO SEMI-CIRCULAR PLATFORMS

Atlas Missile work platform is made up of two separate semi-circular platforms. It is all welded-steel construction, and is



equipped with swivel casters and outriggers for stability.

The rated load capacity is 500 to 1000 lb.

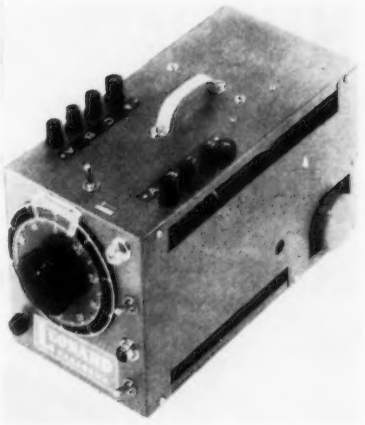
The electrically-operated platform may be built to meet individual requirements for height and size.

Atlas Industrial Corp.

Circle 140 on postcard for more data

RATIOMETER MADE FOR USE IN LAB OR FIELD

A dual channel self-balancing ratiometer for the calibration or adjustment of precision instruments has a guaranteed accuracy of 0.0005 ratio. It can be utilized on potentiometer output instruments, voltage



dividers, initial condition dividers for analogue computers, and many other precision jobs.

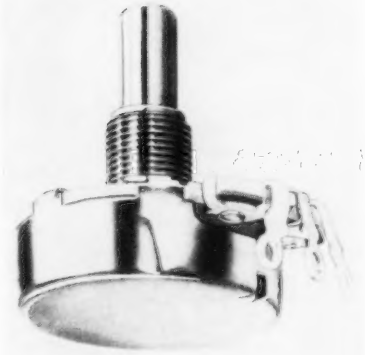
Designated Model 700100-2, it is designed for use on the "flight line" or on "the bench," on normal 60-cyc line voltage.

Wallace O. Leonard, Inc.

Circle 142 on postcard for more data

VARIABLE RESISTOR EXCEEDS MIL SPEC REQUIREMENTS

A high temperature 2-w military variable resistor with greater stability and certified to meet MIL-R-94B Style RV4 has been developed. Ambient operat-

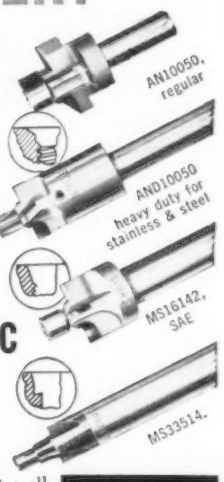


ing temperature of —63 to +150°C exceeds MIL-R-94B.

Type 96 is available with SPST switch, printed circuit terminals, and a variety of

IMMEDIATE DELIVERY

contour cutters for popular hydraulic ports!



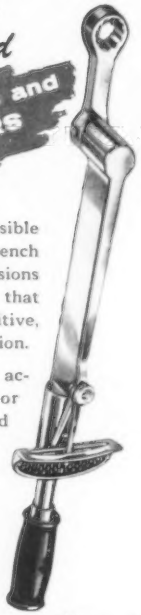
One pass completes all operations necessary to produce the port contour. Job time cut as much as ⅔! All have carbide cutting edges for long life, smooth finishes. Available in all sizes. Write for prices.

SONNET Tool and Mfg. Co.
576 North Prairie Avenue
Hawthorne
California

Circle 11 on Inquiry Card, page 65

Only **ONE** *Torque Wrench can be accurately used with . . .*

EXTENSIONS and ADAPTERS



It is mechanically impossible to use any Torque Wrench with adapters or extensions (with accuracy) unless that Torque Wrench has a positive, built-in, fixed load position.

This essential factor of accuracy, misunderstood or ignored in the design and manufacture of some torque tools, can completely defeat their purpose.

Patented pivoted handle fixes load position

Write for Torque Manual

with formulae tables and explanations for correct use of adapters and extensions

P.A. STURTEVANT CO.
ADDISON QUALITY ILLINOIS

Circle 12 on Inquiry Card, page 65

shafts and bushings. It can also be furnished in two or three sections concentric shaft and straight shaft tandem construction. All insulated parts are nonfungus nutrient hi-temp silicone fibre glass construction. The design has closed openings under terminals.

Chicago Telephone Supply Corp.

Circle 137 on postcard for more data

TESTING MACHINE HAS FIXED CENTER OF TEST

A 10,000-pound tester, in which the center of test always remains at the same point regardless of length of specimen

or amount of extension, is being built; it is the B-L-H Mark G Servomatic.

Constantly situated 56½ inches above the floor, the center of test is easily observed and allows auxiliary test equipment, such as ovens, to remain in a fixed position for the duration of any given test.

The machine is powered with a ¾ horsepower motor and provides a test movement of 20 inches per minute.

In addition to testing samples in tension or compression, the machine is equipped to apply alternating loads. Automatic strain or load cycling is possible at frequencies of from 0.6 to 60 cycles per minute.

Baldwin-Lima-Hamilton Corp.

Circle 154 on postcard for more data

AUTOMATIC WINDER HAS WIRE GUIDES AT REAR

A universal automatic coil winding machine has wire guides located at the rear to give the operator accessibility to the winding.

Model 800-AM winds self-supporting lattice wound universal coils and single or pi-wound R.F. chokes. Wire sizes 20 to 44 can be wound. Winding speed is up to 2000 RPM.

Geo. Stevens Mfg. Co., Inc.

Circle 155 on postcard for more data

COUNTER ADDS OR SUBTRACTS FORTY COUNTS PER SECOND

A line of both uni-directional and bi-directional high speed electro-mechanical counters, able to accept, add, and sub-

tract impulses and function as summation counters, is being produced.

The counters have a life span exceeding 10,000,000 counts. Counting rates range from 15 to 40 counts/sec. Higher speed units are available upon special request. The exclusive, dynamically-balanced incremental actuator is designed to provide absolute accuracy and dependability for a wide range of service.

Digitac, Inc.

Circle 143 on postcard for more data

Laboratory Furnaces

Bulletin S-1055, describes compact, lightweight laboratory furnaces which provide continuous or intermittent operating temperatures from 1000°F (538°C) to over 3350°F (1844°C) for testing or processing small samples. All are suitable for bench mounting and can usually be used without hood.

Selas Corporation of America

Circle 279 on postcard for more data

Brazing

A recently published four-page illustrated folder announces a new brazing aid called Braze-Clad, for combinations of base metals clad with silver brazing alloys. Aircraft components, electronic tube assemblies, carbide tool tips, and welding torch tubing are some of the products incorporating applications of this process.

American Silver Co.

Circle 280 on postcard for more data

Measurement Gage

This two-page, two-color sheet describes a light-weight pistol-grip precision, indicator gage for measuring inside or outside dimensions of "O" and snap ring grooves, bores, recesses, inside spherical radii, and out-of-round conditions.

Mueller Laboratory

Circle 281 on postcard for more data

Production Facilities

A facilities brochure outlines resources, physical facilities, experience, and reputation for quality and service for production of electronic and electromechanical products and assemblies.

Gray Manufacturing Co.

Circle 282 on postcard for more data

Accelerometer Data

Data File 410, a four page bulletin containing illustrations, photos, specifications, and descriptive matter, covering line of vacuum tube and transistorized accelerometers.

Vacuum tube types include Models 4005, 4112, and 4143. Model 4310, a new transistorized accelerometer, is featured on the cover of the data file in a life size photograph.

Donner Scientific Co.

Circle 283 on postcard for more data

Fork-Lift Truck

A four-page folder, illustrating and describing Model F-38T3, 3,000-lb capacity, electric-powered fork truck is highlighted with nearly a dozen illustrations of the truck. Detailed specifications of the model, plus design and application information are included.

Elwell-Parker Electric Co.

Circle 284 on postcard for more data

Loadmeter and Elapsed Time Indicator

Two-page, two-color data sheet describes a 1½ in. aircraft flight instrument (load meter) qualified under the latest military specifications, and a 2½ in. elapsed time indicator.

DeJur-Amsco Corp.

Circle 285 on postcard for more data

Pneumatic Selector Valve

Complete specifications, dimensional drawings, and schematic diagrams of Tactair 9801 four-way, solenoid-operated pneumatic selector valve, developed for use in a rocket release system, are presented on a single-page, two-color data sheet.

Aircraft Products Co.

Circle 286 on postcard for more data

Drive-Pin Rivets

Sample boards of a line of drive-pin blind rivets designed to solve blind-side clearance problems are available. These stainless-steel rivets are being used in the fabrication of thin wings, tails, and for missiles.

Deutsch Fastener Corp.

Circle 287 on postcard for more data

Miniature Couplings

Tiny power couplings, smaller than a car ignition key in length, and with a circumference less than that of a half-dollar are described in Bulletin MC-100. They are for use on servo-mechanisms, computers, missiles, and other devices requiring small-size components

Continued on next page

worth asking for:

technical literature listed here is available without charge from the various manufacturers

Continued from page 71

for power transmission. They are non-magnetic and lightweight, with low elastic yield under torque.

Thomas Flexible Coupling Co.

Circle 288 on postcard for more data

Press Maintenance

A 16mm color and sound film, *High Production Press Maintenance*, describes proper maintenance procedures for high speed presses, including lubrication, adjusting, and checking of clearances. Special emphasis is given to the fast, simple die change-over method, which makes it possible to use such presses even for short runs.

Step-by-step construction of a high production press is shown.

E. W. Bliss Co.

Circle 289 on postcard for more data

Thermocouple Extension Wires

Revised catalog No. 32 illustrates, according to insulation and construction, many types of thermocouple, and extension, wires. Identification symbols of the calibrations and gage sizes in which each type is available are included, as are a number of useful charts with information on calibration symbols and wire color codes, wire resistances, weights, electrical properties, and insulation characteristics.

Thermo Electric Co., Inc.

Circle 290 on postcard for more data

Chemical Treatments of Metals

An eight-page brochure describes various chemical conversion coatings for steel, aluminum, galvanized iron, zinc, and cadmium plated surfaces; for corrosion resistance, paint bonding, drawing and forming, and protection for friction surfaces. Also listed are current specification chemicals for the Government and its contractors.

American Chemical Paint Co.

Circle 291 on postcard for more data

Casting Practices

Product Data Sheet No. 2 gives information on the relation of standard casting practices to pattern and casting design. The importance of considering production factors such as metal shrinkage and minimum section thickness when designing patterns and castings is stressed.

Alloy Steel Casting Co.

Circle 292 on postcard for more data

Vibration Generation Systems

An eight-page bulletin called C10 Series, describes complete complex motion and sine wave vibration generating systems, for use by aviation, missile, and rocket design and test engineers engaged in precise vibration analysis.

MB Manufacturing Co.

Circle 293 on postcard for more data

Air Gage Members

A 20-page manual-type brochure, describing air gage members for all types of circuits (back pressure, flow, and differential). Section on circuit types presents a detailed schematic diagram illustrating the fundamental working principle of each.

Freeland Gauge Co.

Circle 294 on postcard for more data

Subminiature Pulse Transformer

Model ES-3 subminiature pulse transformer, developed in response to demand for units of smaller physical size for use in transistor circuits, is described in a single-page bulletin.

Pulse Engineering Inc.

Circle 295 on postcard for more data

Jigs and Fixtures

Catalog 28 covers over 400 components for jigs and fixtures, and over 200 clamping items. A scale size tracing template of the jig and fixture components is included in the catalog

Northwestern Tool & Engineering Co.

Circle 296 on postcard for more data

All Metal Seal

Engineering details of Conoseal, lightweight, all-metal tubing joint for extreme temperatures and pressures, are inserted in a four-page brochure. Operating range table and three graphs are shown.

Aeroquip Corp.

Circle 297 on postcard for more data

Reinforced Plastics

Bulletin PB7-24 describes a series of "Refrasil" reinforced plastic materials developed for high temperature applications in the missile industry. The five pages include graphs and tables of physical properties.

H. I. Thompson Fiber Glass Co.

Circle 298 on postcard for more data

Soldering Irons

Publication GED-3553, 8 pages, describes and illustrates a complete line of soldering irons. Features of the irons, including lightweight, calorized and ironclad tips, and tubular heater, are explained. Case histories of savings obtained are also included.

General Electric Co.

Circle 299 on postcard for more data

Cobalt Films

Three 16-mm sound films are available to technical, research, industrial, and educational groups.

A Study of Cobalt Deficiency in Ireland, Depositing Stellite with the Oxyacetylene Flame, and *Cobalt in Katanga* are the titles.

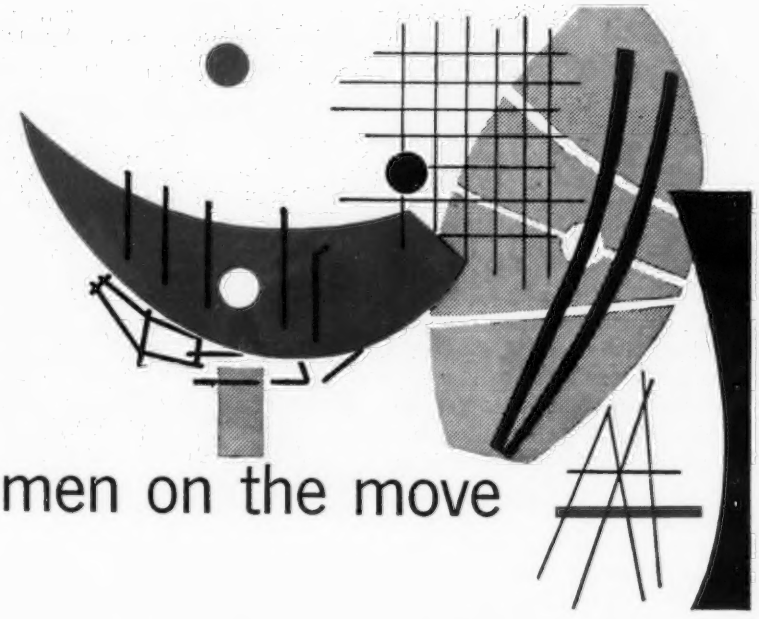
Battelle Memorial Institute

Circle 300 on postcard for more data

DAN E. HARRISON
True-Trace

FRED A. KLEMACH
Vickers

HERBERT C. LANGMORE
North American



men on the move

DAN E. HARRISON has been appointed vice-president and general manager in charge of the Midwestern Div. of True-Trace Sales Corp.

FRED A. KLEMACH has been appointed senior staff engineer specializing in missile applications at Vickers, Inc.

RAY P. WHITMAN first vice-president of Bell Aircraft Corp., is general manager of the new autonomous operating unit called the Niagara Frontier Div.

ROY J. SANDSTROM vice-president, has been assigned the task of planning and directing all projects and activities in the satellite and space travel categories.

PAUL W. WELCH has been appointed New England regional sales manager for Sealol Corp.

GEORGE W. BROOKS has been named to the newly created position of vice-president and general manager of Greer Hydraulics Engineering, Inc.

HERBERT C. LANGMORE has been named manager of special products for North American Aviation's Missile Development Div.

JAMES JARVIE has been named to the new post of general sales manager of Ex-Cell-O's industrial sales organization in Canada.

WESLEY R. KEGERISE has been appointed metallurgist for high temperature alloys by the Carpenter Steel Co.

HOWARD H. DEEM is now director of manufacturing for both Valvair Corp. and Sinclair-Collins Valve Co.

JOHN S. LUND has been promoted to purchasing agent for Lewis-Shepard Co.

EVERETT GRAVENHORST has been appointed director of engineering of the Fluid Systems Div. of the Waldorf Instrument Co.

M. C. CHAMBERS has been elected president of National Machine Products.

VINCENT KAYE has been advanced to director of research and development for Control Engineering Co.

GEORGE B. HARDY has been named manager of the Desiccant Div. of Culligan, Inc.

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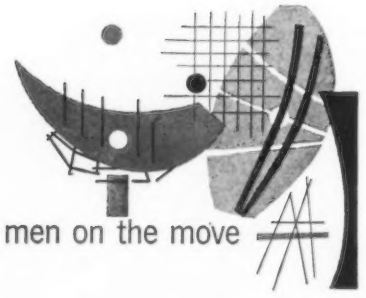


GEORGE P. BULLARD has been named assistant works manager for Kaman Aircraft Corp., Bloomfield and Moosup, Conn., plants. He will have the industrial engineering and plant engineering departments under his jurisdiction.

CHARLES W. ROBINSON has been appointed production manager of the company's plants in Bloomfield, Hartford, and Suffield.

WILLIAM H. HEFFERNAN has been named production manager for prime contract and subcontract manufacturing activities at the Moosup plant.

MATTHEW J. KIELY has been promoted to manufacturing engineer at Moosup. He will direct the planning, tooling, and prototype production of subcontract work.

WILLIAM E. GLENNEY has been named assistant quality manager to head quality operations at Moosup.

DR. MYERS F. GRIBBINS has been named manager of the ammonia products section of the chemical sales division of Du Pont's polychemicals dept.

JAC O. ULLMAN has been promoted to asst. sales manager of the nitrogen products section.

DR. FRANK G. KEENAN has become associate laboratory director for the department's sales service laboratory at Chestnut Run, near Wilmington.

EDMUND M. SCHAUB has been promoted to sales engineer in the metropolitan New York City area for Parker-Hannifin Corp., Cleveland.

RAYMOND J. PFLUM recently retired rear Admiral (USN), been appointed vice-president sales and a member of the board of directors of Napier Engines, Inc., Washington, D. C.

ROBERT J. HOSTETTER has been appointed sales manager of Koehler Aircraft Products Co., a subsidiary of the New Britain Machine Co.

WILLIAM G. FALLON was made a vice-president, director, and executive board member of Norton Co. He was reappointed general manager of the company's Refractories Div.

GEORGE N. JEPPSON was re-elected Chairman of the Board.

MILTON P. HIGGINS was re-elected president.

HOWARD G. SEAMAN was named to the board of directors of th Behr-Manning Co., a Norton div.

WARREN P. TURNER has been named special assistant to the vice-president, High Energy Propellants Div., Olin Mathieson Chemical Corp.

MR. NORMAN E. DONNELY has been selected as a sales representative for the Pittsburgh district sales office of Firth Sterling, Inc. He will cover southwestern Pennsylvania and West Virginia.

W. C. (BILL) WHITEHEAD has been named president of Aerol Associates, a division of Cleveland Pneumatic Industries Inc.

ROBERT ROUNDS was promoted to works manager of the Schrader Div. of Scovill Mfg. Co.

WILLIAM HACKEMANN received promotion to manufacturing superintendent.

CHARLES PASSAGGIO was moved up to chief engineer of industrial products.

RAYMOND J. PFLUM
Napier Engines

WARREN P. TURNER
Olin Mathieson

W. C. WHITEHEAD
Aerol Associates

industry notes

Non-Destructive Testing Is Vital To Development

An intelligent program of non-destructive testing, vital to the reliability check of missiles and rockets, is not only the least expensive of several important test areas, but also can effect large savings, maintains Dr. R. P. Frohmberg, chief of the Production Development Laboratory at Rocketdyne, a division of North American Aviation, Inc., in a paper released recently.

A thorough knowledge of materials processing is indispensible to the efficient use of non-destructive testing. Of equal importance is the discriminate use of testing, and the accurate interpretation of results.

It is a test engineer's responsibility to point out limitations of non-destructive testing to designers. The non-destructive test engineer should be a part of the design team, where he can aid in the intelligent choice of tests.

The ideal non-destructive testing engineer is a "big" man with a big job before him. Considering the missile and defense development programs, it is evident that the job will become increasingly difficult because there will be less development time.

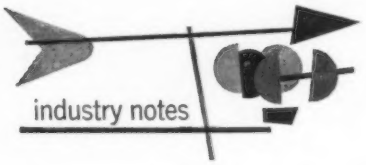
Rear Mounted Jets Are Design Trend in Europe

Within the space of a few weeks preliminary details of proposed new jet airliners have been given by British manufacturers. Four designs have appeared so far to cover the field from short-haul high-density traffic to swift trans-Atlantic crossings. Although not all the designs will reach the flying stage, it is noteworthy that they all have the common characteristic of "rear drive."

Depending upon the particular design either two, three, or four turbojets have been grouped around the rear fuselage. This pattern has already been demonstrated as entirely practical by the French with the *Caravelle* which is powered by two rear-mounted Rolls-Royce Avon engines.

Main attributes of the layout center about the aerodynamically clean wing, absence of exhaust interference and buffet, an almost imperceptible noise level in the cabin, and reduced fire risk. Because there are no wing pods, swollen sections, or leading edge intakes, the wing is devoid of aerodynamic or major structural discontinuities.

In the case of the Vickers *VC.10*, the most promising of the projects offered, the clean wing has been exploited to the full. Long span flaps and full span leading edge slots are employed to give high maximum



lift. These high lift devices may confidently be expected to give a little more than their maximum design lift coefficient because of sink effect provided by the engine positioning. In the case of the *Caravelle* design, maximum lift coefficient with flaps down was 1.97; sink phenomena accounts for the value of 2.12 measured in flight.

The designers claim that wing efficiency has an important bearing upon take-off performance, and that in this direction the *VC.10* is unique. Combinations of hot and high-altitude airfields have been fully designed for since they are met frequently on Empire air routes. From this it appears that a high thrust/weight ratio is employed. Four Rolls-Royce Conway by-pass units are specified but no details of their thrust are given. Using current designs would give an aggregate thrust of some 66,000 pounds but since the type will not enter service until 1963, engines of at least 21,000 lb thrust should be common.

In plan the disposition of areas and their shape make an interesting study. The wing is in strict keeping with previous British practice, that is a medium aspect ratio, about 6.7, combined with a moderate degree of sweep which is broken near the fuselage. Engines are disposed on either side of the rear fuselage at about mid position and with a slight inclination. In effect, these form a stub wing nearly half way between the wing and tailplane with an area nearly as great as the tailplane. These must provide considerable lift at high angles of attack and considerably complicate stability calculations. Sweep of the tailplane is a little greater than that of the wing.

Rearward placing of the engine mass has been compensated by an extraordinarily long front fuselage, in turn this has called for a very large vertical surface. The tailplane, which may be of the moving type, is mounted on top of the fin. Lateral control is provided by ailerons and spoilers, although no official confirmation of this latter item has been made.

A rather interesting feature associated with directional control concerns the way in which the engines toe outwards, the inner units at a greater degree than the outer. Practice on the *Caravelle* has been to keep the engines in the line of flight and angle the jet pipes to toe the thrust line inwards. With this arrangement the failure of one engine makes absolutely no difference to directional trim no matter what the speed.

Accommodation for up to 152 passengers can be provided in the fuselage which has a "double - bubble" cross section. Ample freight stowage is provided in the lower part which is broken into fore and aft compartments by the main wing structure. Little or no engine noise will enter the cabin, but silencers are fitted to the engines for the benefit of airport staff and nearby residents.

Helmet Camera Records Test Flight Data

Flight test engineers at the Columbus Div. of North American Aviation, Inc., need not rely on test pilot's eye-witness reports for data since the innovation of a helmet chase camera.

The eight-pound unit contains two 50-ft reels of 16mm motion picture film. The reels are mounted in matched pairs of modified aircraft gun cameras equipped with a sequence switch which permits instantaneous transfer from the right to the left camera as the right is exhausted.

Both cameras are equipped for finger tip reloading while the pilot is in flight. He can then record as much data as is required during any test flight. Feed and realignment of new film cartridges are accomplished by means of touch, using two posts located over his right ear position. The film may be adjusted to record action at 64, 32,

or 16 frames/sec. Time limits are one, two, or four minutes per load, depending on the frame speed. Motors are electrically driven from the aircraft battery system.

The helmet chase camera has been used to record tank and stores separation from *FJ-3* and *FJ-4* jet fighters produced at Columbus. It is also useful for recording tuft studies showing air flow patterns; aircraft action in spin tests, high speed pullups, and power application and dive brake effects.

It was used once to record damage encountered by an airplane in flight, for study in the event an emergency landing proved unsuccessful. (It didn't.)

Special modifications of the shutters permit a speed of one five-hundreth of a second, or faster. From film so exposed, it is possible to print stills of sufficient quality for research use. This speed also makes it possible for the pilot, except in attitudes of high "G" loading, to photograph his own test instrumenta-

tion. "G" forces above four times gravity tend to make the unit unwieldy. A quick disconnect feature permits the pilot to abandon the whole installation in less than two seconds if an emergency develops.

A sighting mechanism and lens, with 49 adjustable positions, lowers itself into position when the pilot brings down his glare shield. Concentric rings guide his right eye to the photo area. The adjustment feature permits instantaneous adaptation from one man to another. The arrangement of the lens also permits binocular sight. With two units, on two pilots, either may engage in test work, while the other serves as chase airplane, making photos. Three of the sets are currently in use at Columbus where North American has centered its Navy development program.

Translating Russ Books Has Its Problems

The setting-up of a central translation agency to interpret foreign technical publications has illuminated certain failings and fears.

A failing, felt in many other areas, is the federal security curtain. Undue secrecy is still causing duplication, slowing development, and hurting national security. This was brought to light when it was learned that one Russian paper was translated seven times by different agencies; all translations were secret.

A fear, on the part of Congress, is that U. S. translators will waste time on obsolete material on missiles and space travel. The President's technical advisers are telling Congress that the Russian agency (Soviet Institute of Scientific Information) grabs all the U. S. technical magazines and quickly translates and publishes the results, therefore gains much up-to-the-minute knowledge.

Progress Marked In Noise Suppression

Boeing Credits British For 707 Suppressor

Much of the initial success of the noise suppressor for the American *Boeing 707* jet transport aircraft is due to the pioneering efforts of British scientists, the Boeing Airplane Co. declared in London.

After two years of research, the company has developed a multi-tube suppressor for the *707*. Credit is given to the work of the British, notably Professor M. J. Lighthill of Manchester University, Mr. F. B. Greatorex of Rolls Royce, and Professor E. J. Richards of Southampton University.

News of the Boeing noise suppressor follows an earlier announcement that Rolls Royce had developed a "silencer" for the Avon and Conway jet engines, the latter being one which will be installed in the *707* aircraft ordered by BOAC.

N Y Port Authority Checks Jet Noise Level

Tests were carried out recently at Hatfield, England, to measure the noise of the *Comet III* development aircraft. The Port of New York Authority, which last September banned the Russian *TU 104* jet airliner from landing at Idlewild because it had not undergone a noise test, cooperated with de Havilland and Rolls Royce on the test.

A Cambridge (Massachusetts) firm of acoustical consulting engineers made measurements on the Authority's behalf of the noise level of the four Rolls Royce Avon RA 29 jet engines, each rated at 10,000 lb thrust, which were fitted with noise suppressors.

The de Havilland Co. said the suppressors have reduced combined noise level to below that of many large piston-engined aircraft in service.

Optimism Stressed At Machine Tool Meet

Confidence in the ability of the machine tool industry to snap back from the low business level of the past few months was voiced at the 34th Spring Meeting of the American Machine Tool Distributors at New Orleans.

Frank H. Habicht, Chicago, president of the association, told the assemblage, "Being a direct person I believe we should go immediately to the subject that is on everyone's mind today: What about business conditions? More specifically: What about the machine tool business?"

He predicted that we can increase the volume of new orders for 1958 over 1957, in spite of our slow start. "While attending regional meetings I talked with distributors and customers in many different parts of the country. Everywhere I got the feeling of cautious optimism," he declared.

Later in his speech, Habicht said, "Take a specific example that is closer to home—the automotive industry is considered to be one of the largest customers for machine tools. During this currently 'low production' year they will produce more passenger cars and trucks than in any 'high production' year prior to 1950. This isn't hard to believe. Have you been out on the road lately? In my travels I find it takes less and less time to fly across the country, and more and more time to

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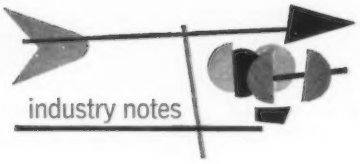

INDUSTRY STATISTICS

Source: Bureau of the Census and Civil Aeronautics Administration.

SHIPMENTS OF COMPLETE CIVILIAN AIRCRAFT AND ENGINES FOR CIVILIAN AIRCRAFT

Item		1957	1956	1955	1954	1953	1952
Complete aircraft, number, total		6,745	7,205	4,820	3,389	4,134	3,509
Under 3,000 pounds airframe weight		6,208	6,778	4,575	3,098	3,825	3,057
3,000 pounds airframe weight and over		537	427	245	291	309	452
Complete aircraft, airframe weight	(1000 lb)	21,368.9	16,202.3	10,230.5	10,493.5	10,373.5	9,322.1
Under 3,000 pounds airframe weight		6,150.7	6,624.4	4,535.9	2,963.0	3,076.3	2,416.1
3,000 pounds airframe weight and over		15,218.2	9,577.9	5,694.6	7,530.5	7,297.2	6,906.0
Complete aircraft, total value	($1000)	$682,264	$454,156	$271,250	$295,738	$244,418	$197,151
Under 3,000 pounds airframe weight		95,883	98,364	63,112	41,402	33,388	23,852
3,000 pounds airframe weight and over		586,381	355,792	208,138	254,336	211,030	173,299
Aircraft engines, number		10,859	11,499	7,639	5,519	6,647	5,382
Aircraft engines, total horsepower	(1000 lb)	7,231.3	5,656.2	3,337.4	3,360.4	4,399.2	2,936.4
Aircraft engines, value	($1000)	$152,456	$108,263	$59,147	$60,647	$70,854	$40,722

NUMBER AND VALUE OF CIVIL AIRCRAFT SHIPMENTS

	Units		Value in Thousands	
Month	1958	1957	1958	1957
January	579	584	$ 62,311	$ 48,431
February		523		49,278
March		675		46,636
April		657		57,980
May		672		84,136
June		590		69,497
July		525		70,649
August		519		62,990
September		466		54,911
October		474		45,687
November		516		47,213
December		544		44,856
Total		6,745		$682,264

AIRFRAME WEIGHTS OF CIVIL AIRCRAFT SHIPMENTS

	Thousands of lbs.		Avg./Aircraft	
Month	1958	1957	1958	1957
January	1,903.2	1,574.9	3,287	2,697
February		1,554.0		2,971
March		1,625.6		2,408
April		1,886.6		2,871
May		2,558.0		3,806
June		2,114.0		3,583
July		2,096.0		3,992
August		1,950.6		3,758
September		1,641.1		3,522
October		1,456.5		3,073
November		1,480.8		2,870
December		1,430.8		2,630
Total		21,368.9		3,168

SHIPMENTS OF PISTON ENGINES FOR CIVILIAN AIRCRAFT

	Units		Value	
Month	1958	1957	1958	1957
January	1,033	920	$ 8,883,000	$ 12,445,000
February		902		13,596,000
March		1,010		13,975,000
April		950		14,388,000
May		1,020		15,160,000
June		933		15,636,000
July		801		12,748,000
August		776		8,603,000
September		728		10,150,000
October		921		13,638,000
November		878		9,880,000
December		1,020		12,237,000
Total		10,859		$152,456,000

TOTAL HP. OF AIRCRAFT PISTON ENGINE SHIPMENTS FOR CIVILIAN USE

	Total Hp. (in Thousands)		Avg. Hp. per Engine	
Month	1958	1957	1958	1957
January	459.9	604.4	445	657
February		647.0		717
March		679.2		672
April		668.2		703
May		715.8		702
June		730.4		783
July		590.4		737
August		425.6		548
September		482.8		663
October		628.3		661
November		473.0		539
December		586.2		575
Total		7,231.3		666

Continued from page 77

drive to the office. What this country really needs is a place to *park*.

"The greatest potential for new machine tool business this year," he said, "is the dire need of all manufacturers to beat the price-cost-profit squeeze, and obtain higher levels of output per man hour."

The Association members also heard addresses by Ludlow King, executive vice-president of the National Machine Tool Builders' Assn., and Louis J. Gober, chief of the engineering branch, Industrial Operations Div., Army Ballistics Missile Agency.

King spoke on loss of employment by Americans as a result of importation and the fact that American manufacturers are "practically being forced" to locate abroad. He pointed out that thirty thousand machine tool employees are laid off. Sixty thousand remain, many on four-day week, some on a three-day week. "I have in mind only the defense of our country," King stated, "nothing of a political or international relationship nature.

"One axiom remains exactly the same as in the days of our forefathers: Only the strong shall remain free!" King declared.

Gober saluted the American Machine Tool Industry as a recognized member of the Ordnance-Industry Team. "As a team, we have been able to do jobs which were classed impossible," he said. "We, as a team, have just repeated an accomplishment of this magnitude, launching the earth satellite, *Explorer*."

A large share, close to 20 per cent, of $33 million furnished by the Government for procurement of facilities to support production of the *Redstone* and *Jupiter* is going for metalworking equipment and small tools.

Concerning future needs, Gober stated, "As new materials are introduced into missile systems, a demand is generated for design and development of machine tools capable of machining the materials and, for specific applications, holding even closer tolerances than are now considered industry standards."

He also referred to automation, and discussed the fact that it is not mandatory for a contractor to accept industrial equipment from reserves.

Analyze Design Factors To Select Tapping Screws

Analyzing design factors instead of using conventional rule of thumb in the selection of tapping screws will provide easier assembly and greater assurance of a sound joint, according to fastener specialists at Russell, Burdsall & Ward Bolt and Nut Co.

There are five common types of tapping screws; two are thread forming, and three are thread cutting. The thread forming screws, types A and B, should be used when the material is ductile enough to permit the deforming action of the screw. Type A is pointed and used in pierced rather than drilled holes and where the exposed point doesn't matter.

Where types A and B screws can't be driven because too much driving effort is required owing to the hardness or thickness of the material, one of the thread cutting screws: types 1, F, or 23 should be used. For hard, ductile materials, type 1 is best; for soft, friable materials, type 23. Type F, which has four equally-spaced longitudinal slots, drives straighter than the other types.

Where load is no factor, thickness of the metal determines the diameter of the screw. Use a screw with thread pitch

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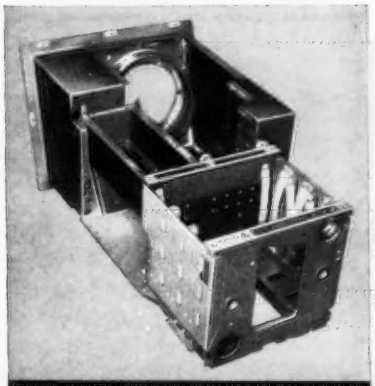
CONVEX?
CONCAVE?
COMPLEX?

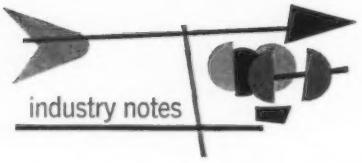


KAMAN
CAN
BUILD IT

HOUSINGS
FOR
AIRBORNE
ELECTRONICS

Complete manufacturing, processing and inspection facilities housed in 500,000 feet of plant space ideally qualify Kaman to produce housings and chassis for even the most intricate airborne electronic equipment. Kaman's experience in producing parts of magnesium and the other aircraft metals to rigid tolerances and specifications has earned it a part in several missiles and rockets programs. Have you considered Kaman? Write for equipment list and illustrated facilities brochure to J.W. Marshall, Manager.

SUBCONTRACT DIVISION
THE KAMAN AIRCRAFT CORPORATION
BLOOMFIELD 5 CONNECTICUT
Circle 19 on Inquiry Card, page 65



that will give at least one full thread engagement in the metal. For example, with metal 0.0625 in. thick, any screw with at least 16 threads/in. can be used.

Where load is a factor, select a screw with sufficient strength and one that provides the greatest thread engagement: four or five threads fully engaged, if possible. If the screw that is large enough to develop sufficient holding power doesn't provide sufficient thread engagement, a greater number of smaller screws should be used.

Size of the hole in the metals to be joined is important. If the hole is too large, the screw cannot develop sufficient thread depth; if it's too small, the screw will be difficult to drive. The required hole size will vary with the thickness of the material, type of material, and style of screw.

Jupiter and Redstone Require Complex Supply

Long range missiles are the most complex weapons system ever devised by man. What they require in supply support, particularly in research and development stage, is staggering.

The Army Ballistic Missile agency at Redstone arsenal places supply responsibility on its Technical Materials and Equipment Branch. It is the responsibility of this organization to order, receive, and issue virtually all of the materials and apparatus used in weaponizing the *Redstone* missile; and developing, testing, and producing the 1500-mi *Jupiter* Intermediate Range Ballistic Missile.

Nearly 300 people in the TM&E Branch operate an inventory of some 61,000 separate items, over 60 per cent of which are "non-standard," that is, items foreign to the normal Army supply inventory.

This long string of materials and equipment is increasing by about 100 items a day. This constant increase is brought about by developments in the missile systems.

The ABMA "department store" issues 3,000 different items a day. Some of these you would expect, like screws, bolts, clamps, capacitors, metals, and chemicals of every thinkable composition and proportion.

But there are also some very improbable items. Take the barrels of vinegar they use as a solvent. Or the several gross of diapers that perform an important function in a lab filtering process. Or the goldfish one scientist uses to determine the oxygen content in water.

The TM&E Branch moves some 2,000 tons of supplies and equipment valued at $1 million every month. This figure is growing, as is the number of employees in the unit. At present most of the supply people are putting in 12-hr days. In the very near future, a second shift, and possibly a third, will be added thus expanding the total personnel by 50 per cent.

This expansion is part of the accelerated production program ordered for the *Jupiter* IRBM. The *Jupiter* is currently produced at the Agency, pending eventual transfer of production to private industry, and the materials are provided through the TM&E Branch.

Storekeepers carry 13,000 individual electrical items, 17,000 in the hardware line, 6,500 in raw materials, 3,500 in small tools, and some 3,700 in chemicals and propellants.

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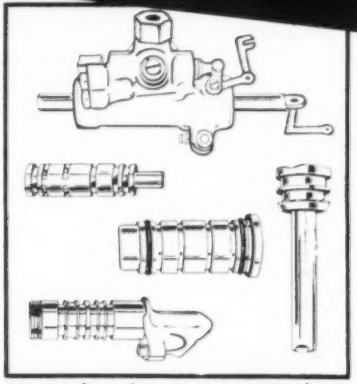

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man in the supply warehouse. For instance, back in one section, where they stock literally hundreds of types of metals of all imaginable compositions and forms, the supply men conduct a unique inspection.

As aluminum materials, long tubes and sheets half as big as a house, arrive from the manufacturer, they are thoroughly scanned with a large magnifying glass to see that they are damage free. In certain areas of the missile, even the tiniest scratch on a piece of sheet metal or tubing cannot be accepted. Hence the rigorous examination, after which the pieces of metal are individually wrapped carefully in paper to assure that each will reach the using laboratory unharmed.

The ABMA is the only organization in the nation that is capable of carrying a long range missile project through all the stages of development, from conception to actual production.

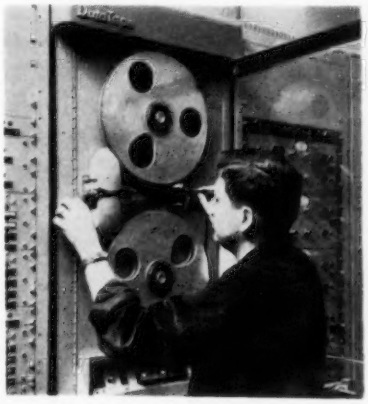
It is a unique operation, and it requires a unique supply organization. Supply managers had to write new supply catalogs. They set up a punch-card inventory and issuing system that would allow them to know precisely what is on hand, and, more important, to allow them to issue it the moment it is needed.

Speed is the great difference between this and the normal Army supply operations. To attain this speed, TM&E Branch has a group of expeditors who "ride herd" on the more difficult and pressing requisitions.

Hi Fi For Satellites

Playing a prominent part in the recent launching of *Explorer*, the first U. S. satellite, was this magnetic-tape recorder/reproducer capable of recording more than 1,800 separate items of information simultaneously.

At Cape Canaveral, which is station No. 1 of the world's largest missile test range, and at down-range stations across the South Atlantic, the recorder/reproducers record telemetry impulses from missiles in flight.



These devices recorded initial data on the launching of the Army's Jupiter-C rocket.

The units were developed for the Air Force Missile Test Center, Patrick Air Force Base, Fla., by Consolidated Electrodynamics Corp., Pasadena, Cal.

Swedish Fighter Presses Mach 2

The Swedish Air Force has decided to make the supersonic "double" delta-wing Saab *Draken* (Dragon) its standard aircraft for fighter, light attack, and other purposes.

The first three *Draken* prototypes have now been undergoing more than two years of intensive flight testing. These tests, mainly carried out in the transonic and supersonic speed ranges, have shown that this advanced aircraft possesses outstanding flight qualities and that performance exceeds expectations.

Like the aircraft's maximum Mach number, its climb performance is still secret, but both are said to be impressive. A developed version of the plane has a speed close to Mach 2. The Saab-35 (*Draken*) is easy to fly and even easier to land than its predecessor, the transonic Saab-

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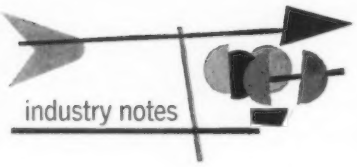

32 *Lansen*. The *Draken's* normal stalling speed is 210 km/h, but it has flown at 190-200 km/h during tests at altitude. It can operate from relatively small airfields, as it requires only 600 meters of runway for landing when using a braking parachute and normal braking. With afterburner, the takeoff run is said to constitute no problem.

The fighter will come into service in about a year and a developed version with a speed close to Mach 2 is expected in the early 1960s.

The equipment will include rockets and air-to-air missiles. The aircraft also has a sight which will permit "direct" attack and thus eliminate the risk of being shot down by the enemy's defensive weapons.

Device Chops Work-time Over 5000 Per Cent

Equipment in use at Boeing Airplane Co., Seattle, is saving time and money in the painting of small parts such as washers, clips, and spacers.

Formerly, this job was time consuming. The parts had to be spread out on a screen and arranged so that one part did not touch another. Then they were sprayed with paint. When the parts were dry, a second screen was placed on top and the entire unit was turned over. The top screen was removed and a second paint spray applied.

This method required a full hour's work by three men for each batch of small parts

that would fit on a screen. By using the new equipment, one man can do the same job in 3½ min.

The Boeing-developed device is a revolving wire-cage drum into which the parts are loaded. An air blast during painting keeps the parts from sticking together. Extremely fast-drying paint is used. Parts are smoothly painted and dry when removed from the tumbler three minutes after being placed in it.

Built from scrap parts around the shop, the "pronto painter" is really paying its way. Painting time has been cut from three hours to 3½ minutes, and the quality of the job is better.

Urgent Need Expressed For Standard Inch

The increasing importance of scientific and technological interchange between the U. S. and friendly nations has made it "urgent that small but significant differences in our measurement standards not create roadblocks to any desirable technological cooperation," Dr. A. V. Astin, Director of the National Bureau of Standards, has declared.

Astin proposed, "Efforts should be initiated to establish an international yard through negotiations with the major English-speaking nations." The new international yard might be defined as 0.9144 of the international meter, yielding an international inch equal to 2.54 cm. "This value is exactly the Canadian standard and about midway between the U. S. and British standards," Astin explained.

Present differences between the three national inches (about one hundred thousandth part of an inch) are greater than tolerances in the millionths for precision components of missiles and other industrial products in some cases. To avoid imminent difficulties in weapons interchangeability, Dr. Astin called for comments from division members on this proposal.

Australia Has No "Inch"

Speaking before the Sydney Chapter of the American Society of Tool Engineers at the Lecture Hall in North Sydney, Australia, U. S. industrialist Louis Polk urged international cooperation among English-speaking and inch-using countries to remove the road block created by the three different inches used by these nations. Australia has not yet established a fixed standard.

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likely to be the most trying phase. Loss of speed would bring the vehicle nearer to earth and there would be an altitude for each steady flight speed. Wing loading will have an important bearing on effects, as indicated in the accompanying table.

If the saucer had been on an interplanetary flight, as distinct from a flight into empty space, it will have an additional velocity due to the sun's gravitational field. All of the velocity in excess of 7 mi/sec would have to be lost in the first entry into the atmosphere, otherwise the vehicle would drift out in an open orbit.

If a high aspect-ratio wing were used a tail would be necessary, but this would burn off. In view of this, spin stabilization is deemed the best. Tip mach cones have been neglected in the rough calculations but their effect upon the static margin can be calculated. The pilot would have to break off often during the deceleration period for cooling purposes but he would be unable to do this below orbit speed. Thus the initial descent phase would likely to be the most trying. Only a slight variation of heating effects could be made by climbing or diving. The final temperature taken up by the hot surface would be somewhat indeterminate; much would depend on radiation rates. In arriving at the temperatures quoted in the table, work done by the vehicle had been calculated as drag times velocity and this reduced to kilowatts per sq ft.

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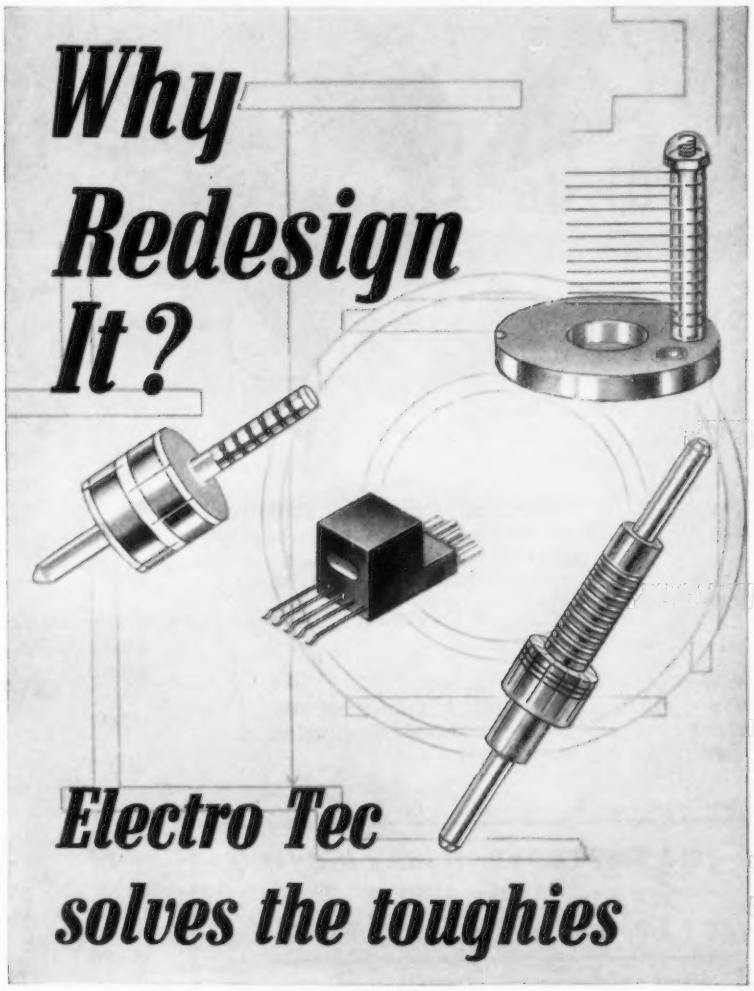

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what annual meeting
who aeronautical training society
where mayflower hotel, washington, d. c.
when april 10-11

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who national aeronautic association
where ambassador hotel, los angeles, cal.
when april 14-16

◆

what design engineering conference
who american society of mechanical engineers
where international amphitheater, chicago, ill.
when april 14-17

◆

what 14th annual national forum
who american helicopter society
where sheraton - park hotel, washington, d. c.
when april 16-19

◆

what second annual technical meeting
who institute of environmental engineers
where new yorker hotel, new york city
when april 17-18

◆

what 14th annual meeting powder metallurgy show
who metal powder association
where sheraton hotel, philadelphia, pa.
when april 21-23

◆

what second annual astronautical symposium
who institute of aeronautical sciences and USAF office of scientific research (AFOSR)
where shirley savoy hotel, denver, col.
when april 28-30

◆

what a.s.t.e. tool show
who american society of tool engineers
where convention hall, philadelphia, pa.
when may 1-8

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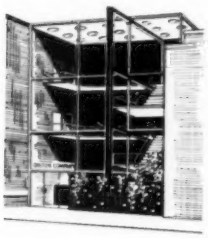

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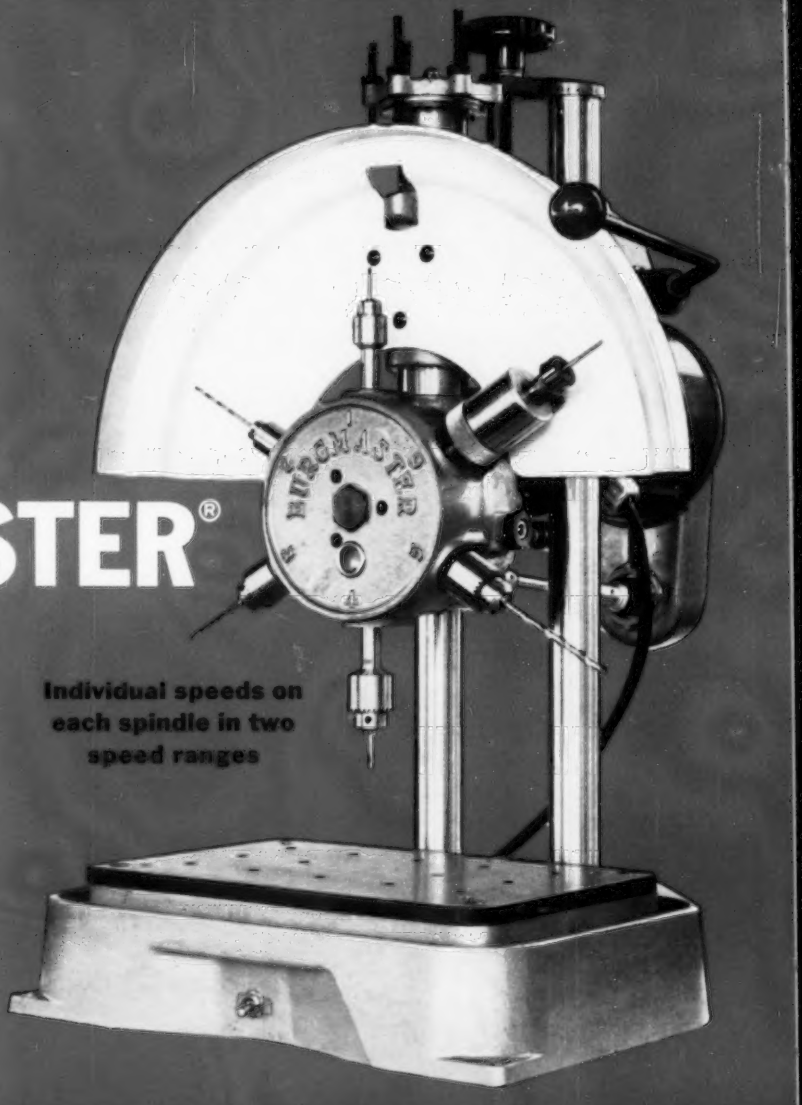

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